King County Brightwater TREATMENT SYSTEM

Technical Memorandum

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King County
Department of Natural Resources and Parks
Wastewater Treatment Division

Brightwater Treatment System

A GEODUCK (*Panopea abrupta*) Survey for the Brightwater Marine Outfall

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EXECUTIVE SUMMARY

King County plans to construct a new wastewater treatment system that would discharge effluent through a new outfall into Puget Sound waters offshore of northern King or southern Snohomish County. King County is conducting a marine outfall siting study (MOSS) for the proposed marine outfall and is preparing the draft Environmental Impact Statement (EIS) for the Brightwater Regional Wastewater Treatment System, which includes the plant, conveyance pipelines and outfall. Existing marine resources, including commercially important geoduck clams (*Panope abrupta*), are important factors in the site selection process.

King County conducted a geoduck survey to supplement existing biological resource information in the vicinity of proposed outfall sites (e.g., King County 2001d, Woodruff et al. 2001). The results of this study will be used to assist in the analysis of outfall sites.

A study plan was prepared and reviewed by Washington Department of Fish and Wildlife (WDFW) and Native American tribes. Population density, show factor, and biomass estimation methodology followed guidelines established by WDFW with modifications for site-specific conditions. Included in this plan were 29 grid lines, 2 show factor plots, habitat documentation, biomass, and commercial quality estimation of collected geoducks.

The quantitative survey was conducted along 11.3 kilometers (7 miles) of shoreline from north of Edmondsto south of Point Wells. The study area extended from 21.3 meters (m) (70 feet [ft]) below mean lower low water (- 21.3 m MLLW) up to the lower edge of the intertidal zone.

The geoduck survey was conducted from April 8, 2002 to May 10, 2002. A total of 92 scuba dives were logged in 17 working days. Approximately 5,989 m (19,650 ft) of grid lines were examined by scuba diving within the study area. During the examination of each strip transect, geoducks were enumerated and other shellfish species, sediment type and other habitat characteristics, and associated biota were noted. In addition to geoducks, attention was paid to *Tresus* sp. (gaper clams), rockfish species (*Sebastes* sp.), and crabs including Dungeness (*Cancer magister*), graceful (*C. gracilis*), and red rock (*C. productus*) crabs. The lower edge of eelgrass (*Zostera marina*) beds, macroalgae assemblages, and substrates was also noted. Geographic coordinates of bed boundaries on each line were recorded for Geographic Information System (GIS) mapping.

Differences in habitat characteristics were noted; the predominant habitat is a sandy or mixed substrate type with little macroalgae. Three divisions or sub-areas based on habitat characteristics within the study area were found as follows:

- North of the Edmonds Ferry Terminal
- Between the Edmonds Ferry Terminal and Point Edwards
- Point Edwards to the Southern Boundary of the Study Area, including Point Wells

The lower edge of eelgrass throughout the study area is approximately - 5.6 m (18 ft) MLLW). The exception to this was on Line 12, which is in conceptual zone 6. Here the lower edge of a relatively dense bed was between 0 and –0.3 m (1 ft) MLLW.

An average geoduck show factor of 0.83 was calculated from the two show factor plots. Mean geoduck density in the study area was 0.84 geoducks per square meter (0.08 per square foot). Mean geoduck weight and biomass in the study area was 1.06 kilograms (2.34 pounds) per geoduck and 8,920 kilograms per hectare (8,154 pounds per acre).

Statistical analysis did not indicate that geographic divisions within the study area are significantly different in geoduck population density, but are different in individual geoduck weight. Geoduck population density was also significantly different by depth zone with the densest populations in the greater depths. Individual geoduck weight was also significantly different with the heavier geoducks found in shallower water.

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1.0 INTRODUCTION

In November 1999, the Metropolitan King County Council approved the Regional Wastewater Services Plan to upgrade King County's existing wastewater system (King County Ordinance 13680, Nov. 23, 1999). Included in this plan is the construction of a new regional wastewater treatment plant (WWTP) in either northern King or southern Snohomish County. The new treatment plant will have a marine outfall to discharge treated effluent to Puget Sound in either northern King or southern Snohomish County.

Using King County Council-adopted policy siting criteria the County conducted two phases of outfall site analysis in 2000 and 2001. These policy siting criteria were used to identify suitable locations for the outfall and diffuser in northern King and southern Snohomish counties. At the conclusion of the second phase of outfall site selection, the King County Council Accepted four candidate marine outfall zones, 5, 6, 7N, and 7S, for further analysis and review (King County Ordinance 14278, Dec. 13, 2001; Figure 1). Each zone contains one potential diffuser site with the exception of Zone 7S, which contains two. Reports produced from the siting studies should be consulted for complete details of the Phase 1 and Phase 2 outfall site selection process to date (King County 2001a, b, and c).

The outfall study area includes a variety of biological habitats and communities. Eelgrass meadows (*Zostera* sp.) are prevalent (King County 2001d, Woodruff et al. 2001). Geoduck beds are ubiquitous in and below the nearshore area (KCDNR 2000, Sizemore and Ulrich 2001), which has been defined by the King County Nearshore Technical Committee (Williams et al. 2001).

The Washington Departments of Fish and Wildlife (WDFW), Natural Resources (WDNR), and Health and local Native American tribes have management and public use responsibilities for geoduck (*Panopea abrupta*) resources in the vicinity of the candidate outfall zones. Geoducks and other commercially important clams may potentially be impacted directly by construction or by the release of wastewater from the outfall.

As part of King County's site selection process, documentation of existing marine resources is necessary. This is particularly important in the case of the commercially important geoducks and ecologically sensitive habitats. Eelgrass beds were documented and mapped by KCDNR (KCDNR 2000, Woodruff et al. 2001, King County 2001d). King County initiated a geoduck resource study in spring 2002 to supplement and update existing information in the vicinity of the candidate outfall zones.

This geoduck study includes the following components:

- A quantitative delineation of geoduck resources.
- Documentation of the presence and relative abundance of associated biota including commercially important crabs and clams, and sensitive rockfish populations.
- Confirmation of the distribution of eelgrass (*Zostera* sp.) in the study area.

Within this report, all measurements are presented in SI units (metric) with the English equivalent in parentheses. Additionally, coordinates for all positions in this report are listed as latitude and longitude (Datum is NAD83) and Washington State Plane (NAD83, Zone North 4601).

2.0 METHODS

2.1 Study Area

The study area for the geoduck survey extends along approximately 11.3 kilometers (km) (7 miles [mi]) of shoreline. Coordinates for the boundaries of the study area are listed below.

- North
  - 47°49.776'N Latitude, 122°22.224'W Longitude
  - Northing 93385.6 meters (m) (306382 feet [ft]), Easting 384931.5 m (1262896 ft)
- South
  - 47°46.314' N Latitude, 122°23.912'W Longitude
  - Northing 90719.5 m (297635 ft), Easting 382770.5 m (1255806 ft)

This area encompasses the four candidate outfall zones designated by King County Council as possible locations for placement of the outfall (Figure 1). The areas between each zone and 0.8 km (0.5 mi) to the north of Zone 5 and south of Zone 7S within the same depth limits are also included in the study area (Figure 1).

The geoduck survey was conducted in the subtidal zone within the study area between approximately 1.2 m (4 ft) below mean lower low water (-1.2 m [4 ft] MLLW) and – 21.3 m (70 ft) MLLW. The lower boundary was chosen because WDFW and WDNR allow and manage commercial geoduck harvesting down to, but not below this depth. The upper limit for this survey was selected because of past direction from WDFW to environmental consultants that are conducting geoduck surveys. WDFW generally requests that all consultant surveys extend up to the intertidal zone because of interest by local Native American tribes (e.g., Tulalip Tribes) in geoduck and gaper clam resources between the intertidal zone and - 5.5 m (18 ft) MLLW.

2.2 Population Density Estimation

The study design for the MOSS geoduck survey was based on WDFW protocols for geoduck surveys as described in "Stock Assessment of Subtidal Geoduck Clams (*Panopea abrupta*) in Washington" (Bradbury et al. 2000). Other sources of sampling design were available including advice from the Tulalip Tribes (McHugh 2002a) and various references on scientific sampling (e.g., Baker and Wolff 1987, Green 1979, Gunderson 1993). The WDFW methodology was chosen over other sampling designs because of the following:

- Need for comparability to historical surveys by WDFW, Tribes, and consultants using the WDFW methodology.
- The general use of the WDFW methods by WDFW, WDNR, and Tribal shellfish biologists throughout the region.
- Need for standardized methodology to allow future use of this survey as a baseline for future impact evaluation, monitoring, and/or management studies.

- WDFW and WDNR as regulatory agencies would likely be reviewing and applying the survey results for management purposes.

The WDFW sampling methods were only modified to meet specific requirements of this survey and for personnel safety. Modifications are noted in the following description of survey methods. WDFW was consulted during the preparation of the sampling plan to ensure comparability and compatibility with WDFW geoduck survey protocols (Sizemore 2002a, b, and c). This sampling plan was reviewed and approved by WDFW (Sizemore 2002b). The WDFW approved sampling plan with comments by Sizemore (2002b) and McHugh (2002) is found in Appendix C of this report.

2.2.1 Geoduck Population Survey

As in WDFW geoduck surveys, the primary sampling unit for the MOSS geoduck survey was "grid lines"[1] (line) that were established along the shoreline every 305 m (1,000 ft) using a geographic – referenced geographic information system (GIS) map of the study area. The upper and lower positions of each line (– 24.4 m (80 ft) MLLW) were initially obtained from this map. A total of 26 lines were placed perpendicular to the shoreline from north boundary to the south edge of the study area (Figure 2).

Along each line, a series of "strip transects"[2] (herein after referred to as transects), the secondary sampling unit in WDFW methodology, were examined by scuba divers for geoducks and associated species. Each transect was 1.8 m (6 ft) wide and 45.7 m (150 ft) long covering 83.6 square meters (m^2) (900 square feet [ft^2]).

In addition to the lines placed at 305-m (1,000 – foot) intervals along the shore, conceptual pipeline alignments were examined in three of the four candidate outfall zones. These conceptual alignments represent possible outfall pipeline corridors, based on present knowledge of the bathymetry within the zones and possible terminus of the Brightwater conveyance system.

A precision underwater positioning system known as "AquaMap™" (Desert Star Systems) was employed during the examination of the conceptual alignments. Using the AquaMap™ system allowed the survey divers to follow a specified alignment with minimal (0.3 m or 1 ft) horizontal error. AquaMap™ was used only on the conceptual alignments in Zones 6, 7N, and 7S (Figure 2) because of the need to maintain precision in diver positioning on the alignments.

Two qualified geoduck survey biologists using scuba equipment, a fiberglass survey tape, and 0.9 m (3 ft) wide "t – bars" examined consecutive transects along each line (Figure 3). Each diver examined an area 0.9 m (3 ft) wide and 45.7 m (150 ft) long. Two divers swimming independently but parallel and together has been used in prior surveys with

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[1] "Grid line – The primary sampling unit in geoduck surveys, along which a series of 900 ft^2 strip transects is aligned; usually run perpendicular to shore." ((Bradbury et al. 2000: page v, Glossary).

[2] "Transect – The secondary sampling unit for geoduck density. In this report, [sic] a standard strip transect 150 ft long by six [sic] ft wide (=900 ft^2) within which divers count all geoducks which are 'showing.' " (Bradbury et al. 2000: page vii, Glossary).

WDFW approval (e.g., Kyte 1997, 1999). In addition, this method was employed successfully with shellfish biologists from the Tulalip Tribes in 2001[3].

During the survey, the position of the – 21.3-m (70-foot) contour on each line (deep end) was located using a Global Positioning System (GPS) receiver with a resolution of approximately 3 m (10 ft) to 4.5 m (15 ft). A marker buoy was placed on the – 21.3-m (70-foot) contour and was used by the divers to descend to the starting position. The divers then followed a compass course towards the line's inshore terminus (shallow end)[4]. Following the direction of WDFW, a random distance of 0 to 3 m (10 ft) between the buoy anchor and the start of the first transect was used to introduce a random element into the sampling (Sizemore 2002b).

Geoduck surveys along each line were terminated at the first encounter of rooted eelgrass[5] or at –1.2 m (4 ft) MLLW. A buoy was placed at the shallow end of the line and coordinates of this location were recorded from the GPS receiver.

Along each line, sediment types and associated biota were noted. In addition to geoducks, attention was paid to *Tresus* sp. (gaper clams) (Figure 4), rockfish species (*Sebastes* sp.), and commercially harvestable crabs including Dungeness (*Cancer magister*) (Figure 5), graceful (*C. gracilis*), and red rock (*C. productus*) crabs. The lower edge of eelgrass beds, the presence of macroalgae assemblages, and substrates were also noted.

2.2.2 Show Factor Study

A study was conducted to determine a season and site-specific show factor. The show factor is the proportion of a geoduck population that can be counted visually at any one time. Determination of a site and time specific show factor allows the counts of geoduck siphons or "shows" in each transect to be adjusted to reflect true abundance by using the following formula (Bradbury et al. 2000).

Formula 1: Show Factor = S = n/N

n = the number of visible geoduck shows recorded on the first survey of the "show plot"[6]
N = the sum of all shows counted in the show plot

Due to the size of the survey area two show factors were estimated, one near each end of the survey area, (Figure 2) (geographic coordinates are present in Table 3 of Appendix A). The 83.6 m² (900 ft^2) show plots were placed between – 12.1 m (40 ft) and –15.2 m (50 ft) MLLW and marked to allow re-examination of the same area. A GPS receiver was used to

[3] WDFW geoduck surveys are conducted using a solid 1.8 m (6-foot) rod with a line reel in the center. Two divers swim together, each holding the pole and counting geoduck shows. The method used for the MOSS study was adopted to provide greater flexibility and safety for the divers.

[4] WDFW geoduck surveys are conducted from the shallow end of each grid line into deeper water. This practice does not achieve optimum safety for the survey divers. Thus, divers in this survey traveled from deep to shallow to minimize exposure to greater depths.

[5] Clam harvesting in eelgrass or within 0.6 vertical m (2 ft) of the lower edge of a bed is prohibited by the State of Washington. In addition, geoduck relative density in eelgrass is usually low. Thus, assessments within eelgrass beds are not usually conducted.

[6] "Show plot – Permanently-marked subtidal areas in which the absolute number of harvestable geoducks is known from repeated tagging; show plots are used to estimate geoduck show factors." (Bradbury et al. 2000, page vi, Glossary).

return to the show plots. The total number of harvestable (i.e., countable) geoducks was determined by repeated counts and tagging of observed geoducks until no additional new shows were found during a standard examination (Figure 6). The show factor study was completed within seven days and the average show factor was used to adjust all geoduck siphon counts.

2.2.3 Biomass Estimation

In addition to population density, information was obtained on the biomass of geoducks within the study area. Geoducks were collected and weighed following WDFW methods (Bradbury et al. 2000, Sizemore 2002c) after completing the geoduck population survey. Transects with an adjusted density of 0.4 geoducks/m^2 (0.04/ft^2) or greater were selected for geoduck sampling. This is the threshold density used for biomass sampling and commercial harvesting as set by WDFW (Bradbury et al. 2000). In addition, experience with finding and digging geoducks gained on this survey and previous studies (e.g., Kyte 1997, 1999) demonstrated that in areas with densities less than this threshold too much time is required for the diver to locate geoducks for sampling.

Eligible transects were numbered, and one was chosen randomly to serve as a starting point. From this point, every sixth eligible transect was selected for sampling according to WDFW protocols (Bradbury et al. 2000, Sizemore 2002c). This procedure ensured that sample points were spread throughout the study area.

A series of cluster samples, consisting of five geoducks each, were collected using a water jet from selected transects. The first five geoducks encountered by the sampling diver in each selected transect were collected. Geoducks were weighed, measured, and photographed on the dock (Figures 7 and 8). Weight was estimated as an average live wet weight, including shell, of an individual geoduck. In addition to weight, the right shell of each geoduck was measured for correlating weight and length (Figure 9).

Geoducks cannot be returned to their habitat with a reasonable chance of survival. In addition, it was necessary to prevent the collected specimens from entering the public market because the study area has not been certified for harvesting. Thus, all collected geoducks were donated to the Seattle Aquarium.

2.3 Grading

In response to a request from the Tulalip Tribes (McHugh 2002a), photographs were taken of the geoducks obtained for biomass. These photographs were submitted to the Tulalip Tribes for grading of the sampled geoducks. McHugh (2002b) describes the details of the grading methods in Appendix B.

2.4 Calculations

The formulas used to calculate density, biomass, and estimate precision were obtained from WDFW protocols (Bradbury et al. 2000) are as follows:

Formula 2: Density of Geoducks in *i*th quadrat = $d_i = d_{obs}/S$

d_{obs} = density of observed geoducks on a transect (number per unit area)

S = show factor

Formula 3: Overall Density of Geoducks = $D = \Sigma d_i/n_D$

nD = number of transects surveyed

Formula 4: Variance of the mean density = $\delta^2_D = n_D \Sigma d_i^2 - (\Sigma d_i)^2 / n_D (n_D - 1)$

Formula 5: Standard error of the density = $SE_D = \sqrt{\delta^2_D} / n_D$

Formula 6: Coefficient of variance for the estimated density = $CV_D = SE_D / D$

Formula 7: 95 % Confidence interval for the estimated density = $CI_D = D \pm t \times SE_D$

t = 1.96 for $\alpha = 0.05$, a factor based on the degrees of freedom, which equal n – 1 (Elliott 1971).

Formula 8: Estimated mean weight per geoduck = $W = \Sigma w_i/n_W$

wi = weight of the ith geoduck from collected samples

nW = sample number for weight

Formula 9: Variance of the mean weight per geoduck = δ2W = nW Σ wi 2 - (Σwi) 2/ nW (nW – 1)

Formula 10: Standard error of the weight estimate = SEW = √ δ2W / nW

Formula 11: Coefficient of variance for the estimated weight = CVW = SEW / W

Formula 12: 95 % Confidence interval for the estimated weight = CIW = W ± t x SEW

t = 1.96 for $\alpha = 0.05$, a factor based on the degrees of freedom, which equal n – 1 (Elliott 1971).

Formula 13: Biomass estimate = B = (D)(W)

In order to use the above formulas from WDFW (Bradbury et al. 2000), it must be assumed that data on geoduck population counts and weight determinations are normally distributed. In addition, parametric statistical tests were applied to these data to determine significant differences within the study area.

3.0 RESULTS AND DISCUSSION

3.1. Existing Information

The WDFW Geoduck Atlas for 2002 (Sizemore and Ulrich 2002) list and describes two geoduck tracts (06000 and 06100) in the study area. Both were surveyed by WDFW, with the most recent surveys in 1980 on tract 06000 north of Edmonds. The two tracts are designated by WDFW as not available for harvest because of water quality concerns (Sizemore and Ulrich 2002).

Pentec Environmental (1995) conducted a reconnaissance survey of marine resources along the Edmonds shoreline in preparation for relocation of the Edmonds Ferry terminal. Eelgrass and macroalgae beds with Dungeness crab, geoduck, and hardshell clam populations were documented within the study area.

The KCDNR MOSS conducted initial surveys in and around the study area (KCDNR 2000, Woodruff et al. 2001, King County 2001d).

3.2. Schedule

WDFW guidelines specify that geoduck surveys must be conducted between March 1 and October 15 (Bradbury et al. 2000). Geoducks cannot be accurately counted outside this period, as they are dormant. As a result of their dormancy, geoducks do not show and cannot be counted reliably resulting in show factors that are too low (i.e., less than 0.5) (Bradbury et al. 2000, Goodwin 1977, Sizemore 2002b). The geoduck survey was initially started on March 5, 2002. However, because of a low (0.48) show factor, erratic showing behavior, and unfavorable weather, the survey was postponed until April 8, 2002. The survey with show factor and biomass studies required 17 working days and was conducted between April 8 and May 10, 2002. During the survey, a total of 92 scuba dives and 83.7 diver-hours underwater were logged.

3.3. Grid Line and Alignment Characteristics

Geographic coordinates (latitude, longitude, and Washington State Plane) of the offshore and inshore ends and intermediate points of the lines and conceptual alignments are presented in Table 1 of Appendix A. Depths and lengths examined are also in Appendix A. A total of 26 lines containing 140 transect, 3 conceptual alignments, and 2 show plots were examined in this study. Line and alignment cumulative total length was 5,989 m (19,650 ft).

Table 1
Summary of Substrate Observations with the Lower Edge of Eelgrass in the MOSS Geoduck Study Area

	Eelgrass Lower Edge (MLLW)		
Grid Line or Conceptual Alignment	**Meters**	**Feet**	**Dominant Substrate Type**
1	7.9	26	sandy
2	3.0	10	fine sand to gravelly sand
3	4.0	13	fine sand, silty sand, to gravelly sand and cobble
4	7.3	24	fine sand
5	5.5	18	fine sand to silty sand
6	ND	ND	silty sand to coarse silty sand and gravel
7	ND	ND	sandy
8	6.4	21	fine sand to silty sand
9	7.9	26	silty sand, old outfall and phone cable
10	NP	NP	steep silty sand to gravelly sand slope and riprap
11	NP	NP	fine sand, cobble, shell debris to gravel and riprap
12	0.3	1	steep gravel and sand slope to sand flat
13	0 to 0.3	0 to -1	firm gravel and sand to gravel and cobble with shel debris
14	5.5	18	coarse sand, gravel to fine sand
15	3.4	11	sandy
16	7.3	24	sandy
17	5.6	19	sandy
18	6.7	22	fine sand to silty sand
19	6.4	21	sandy
20	6.1	20	sandy
21	6.1	20	gravelly sandy to mixed coarse gravel, cobble, san to silty sand
22	3.7	12	fine sand and shell debris
23	7.9	26	coarse sand
24	ND	ND	sandy
25	6.1	20	sandy
26	7.0	23	sandy
Alignment 6	0 to 0.3	0 to -1	gravel and silty sand to sand and gravel
Alignment 7 N	5.2	17	sandy
Alignment 7 S	3.7	12	gravelly sand
Show Plot N	ND	ND	sand mixed with pea gravel
Show Plot S	ND	ND	sandy
Average Depth of Eelgrass	5.6	18.4	

ND = not determined

NP = not present

3.4. Sediment and Habitat Types

The predominant sediment type throughout the study area was sand (Figure 3) often with gravel of varying sizes (Figures 4, 5, and 6). The sand varied from silty sand to coarse sand. Other incidental substrate included cobble, shell debris, riprap, logs, and anthropogenic debris (Table 1). According to the WDNR habitat classification system for Puget Sound, the dominant habitat type above –15 m (49 ft) MLLW is "Estuarine Subtidal Sand: Open, Shallow" and below –15 m (49 ft) MLLW is "Estuarine Subtidal Sand: Open, Deep" (Dethier 1990). Where gravel and other larger particle sizes is prevalent, the habitat type is mixed-fine or mixed-coarse depending on the amount of silt and clay present.

As documented by Woodruff et al. (2001) and King County (2001d), several sections of shoreline support eelgrass beds. The average lower edge of eelgrass is approximately –5.6 m (18.4 ft) MLLW. Table 1 shows the lower depth where eelgrass was encountered on each grid line. An exception to this eelgrass distribution occurs on Line 12 and Alignment 6. Here, eelgrass is present in a relatively dense bed at the upper edge of a broad intertidal flat. The eelgrass bed is on the north side of the existing Unocal pier and extends to the north. This eelgrass bed was not noted in previous King County surveys because its shallow depth renders it inaccessible to the survey methods used in the surveys.

Geographic features, urban development, and natural shoreline characteristics defined three distinct sub areas within the study area as follows:

A. Edmonds Ferry Terminal north to the study area boundary

B. Edmonds Ferry Terminal to Point Edwards as marked by the existing Unocal pier

C. Point Edwards to the southern boundary of the study area including Point Wells

Within the three sub areas, a few individual lines and conceptual alignments were found to have characteristics that distinguished them from the sub area in which they were located. The candidate outfall zones were superimposed on the grid line and sub area maps (Figures 1 and 2). Observations on substrate and habitat characteristics for the sub areas and lines or alignments are presented in the following sections and Table 1.

3.4.1. Sub Area A: North of the Ferry Terminal

Data from Lines 1 through 7 were used for calculation of geoduck population density and biomass in Sub Area A.

The Edmonds Underwater Park, a marine protected area established by the City of Edmonds, is located at the southern edge of the sub area adjacent to the ferry terminal. Because power vessels are not allowed within the park because of potential danger to recreational scuba divers using the park, the survey was stopped at the park boundary, which was indicated by buoys on the surface and structures on the bottom. Thus, Lines 6 and 7 were terminated offshore of the upper limit of other transects (Table 1 in Appendix A).

This sub area and all transects within the area north of the ferry terminal were characterized by broad relatively uniform sand flats. On Line 5, isolated large glacial erratic boulders were encountered. These boulders offer substrate for encrusting organisms and are colonized by anemones (e.g., *Metridium* sp.), moss animals (Bryozoa), barnacles (*Balanus* sp.), and other taxa. In addition, a cabezon (*Scorpaenichthys marmoratus* - a demersal fish) was seen using one of these boulders for egg deposition.

On other lines (e.g., 3, 6, and 7) patches of gravel or cobble mixed with sand (i.e., “mixed coarse”) were encountered. These areas typically support red (Rhodophyta) foliose algae with densities (i.e., percent cover) up to 100 percent.

Eelgrass (*Zostera marina*) was encountered on all transects in this area, except those terminated at the outer edge of the Edmonds Underwater Park, at or below approximately –5.4 m (18 ft) MLLW.

3.4.2. Sub Area B: Ferry Terminal to Point Edwards

Sub Area B includes Lines 8 through 13 and is characterized by a heavily modified and urbanized shoreline and nearshore subtidal zone. The Washington State Ferry Edmonds terminal and ferry approach lanes form the northern boundary of this sub area. The City of Edmonds Marina and public fishing pier and the breakwater for the Edmonds Marina are present on the shoreline within Sub Area B. These features necessitated modification of some of the lines. For example, Line 8 (Figure 2) was angled to the south to avoid the ferry approach lane.

A former Edmonds WWTP outfall, an artificial reef established by WDFW in 1977, and the recreational Edmonds fishing pier at the north end of the marina are present on Line 9. The presence of these features caused portions of the substrate to be unavailable to surveyors.

The Edmonds Marina offshore breakwater is present on the inshore ends of Lines 10 and 11. Because of steep slopes and the presence of breakwater riprap, both lines consisted of only one transect (Tables 1 and 4 in Appendix A). The substrate on both lines was gravely sand with occasional riprap boulders that had moved down the slope from the toe of the breakwater.

A marine terminal formerly occupied by Unocal is present on Edwards Point south of the Edmonds Marina. There is a marine protected area established by the City of Edmonds between the existing pier and the south end of the Edmonds Marina.

Line 12 was located in an area with a relatively steep sandy gravel slope that has an incline of approximately 3:1 (vertical:horizontal). The gravel on this slope is mobile and was observed to move down-slope with little disturbance. The top of the slope, the shallow ends of the lines, was at the lower edge of the intertidal zone on a sand bar.

One reason for the relatively extreme slopes and large intertidal sand bar encountered on Line 12 is that this area is at the terminus of a littoral processes drift cell (Schwartz and Bronson 1984, Johannessen 1992). The shore-drift terminates against the Edmonds Marina breakwater and the sediment is redirected offshore and along-shore in the form of a large sand bar whose offshore side forms the upper part of the steep slopes.

A relatively dense contiguous bed of eelgrass is present above the end of Line 12 and candidate Alignment 6 at the base of the high tide berm. The approximate tidal level of the eelgrass is between 0 and –0.3 m (1 ft) MLLW. Pentec (1995) also described the eelgrass bed at this location.

Line 13 is located off the south side of the existing Unocal pier. Abundant anthropogenic debris was encountered along this line in the form of large tractor tires used as fenders by tugs and other vessels, logs, ballast rock, and other items. Eelgrass was not found on Line 13.

The slope on these transects was too steep and mobile to allow geoduck harvesting for biomass samples. In addition, the substrate on Lines 10, 11, and 13 was too coarse to allow harvesting.

3.4.3. Sub Area C: Point Edwards to the Southern Boundary of the Study Area

Lines 14 through 26 and conceptual Alignments 7N and 7S are included in this sub area. Conceptual Alignment 7N is located north of Point Wells and crosses an area of broad intertidal sand flats. Conceptual Alignment 7S lies along the south side of Point Wells.

The Point Wells Chevron Asphalt Facility with a large pier is located on Point Wells. Another pier is located on the north side of the point and shoreline armoring is present.

According to KCDNR (2000), the nearshore area between Point Edwards and Point Wells contains a broad expanse of eelgrass and kelp beds. However, no kelp beds were seen during the survey even though kelp was encountered in Sub Area A. Patchy eelgrass was present at the inshore end of each line with the lower edge at approximately – 4.9 to 6.1 m (16 to 20 ft).

Eelgrass was encountered on relatively steep slopes below the edge of the intertidal zone on Lines 21 and 22 (Table 1). On Line 23, deposits of uprooted eelgrass were found in shallow ravines leading offshore from the intertidal zone. Eelgrass was not found above these ravines or at the upper end of the line. Patchy eelgrass was found well below the intertidal zone on Lines 24 through 26 as shown in Table 1.

Lines in this sub area were generally characterized by moderately sloping sandy substrates with broad intertidal sand flats. Gravel, erratic boulders, and other features were generally absent from the subtidal zone except in specific areas. Line 21, on the north side of Point Wells has gravely sand (mixed coarse) at the offshore end. This substrate grades into silty sand. This substrate prevails to the toe of a steep sandy slope descending from the intertidal zone. On the nearshore portion of this line, abundant anthropogenic debris was found including sunken piling, logs, metal debris, and other materials. The remnants of the offshore end one of the existing Point Wells piers were found on the inshore end of Line 21. These remnants consist of a cluster of piling (dolphin) and several sunken piles.

On Lines 22 and 23 and conceptual Alignment 7S, terraces with relatively steep front slopes are found down to - 21.3 m (70 ft) MLLW. These terraces are covered with mobile sand, which was observed to be moving down slope.

The type of substrate found around Point Wells may occur because the oil terminal piers and shoreline armoring with the natural structure of the point partially block and redirect offshore the northward movement of sediment. Point Wells is in a shore-drift cell that terminates at Point Edwards and the Edmonds Marina as discussed above (Schwartz and Bronson 1984, Johannessen 1992). The sandy terraces and ravines on the south side of the Point likely exist because of the offshore movement of sediment. In contrast, the silty and more depositional nature of Line 21 is likely due to sediment – starved conditions stemming from its location on the north or up-gradient side of Point Wells.

Lines 24 through 26 are south of Point Wells and Alignment 7S. These lines are also south of the influence of Point Wells as discussed above. These three lines are characterized by similar conditions as seen between Point Wells and Point Edwards.

3.5. Associated Biota

The biota observed in the course of the geoduck survey is typical of Central Puget Sound finer sedimentary environments (Kozloff 1983, Dethier 1990). Table 2 lists the species observed along the survey lines. This biota is characterized by a low number of species and individuals except for infauna taxa (animals living within the sediments) such as geoduck and gaper (*Tresus* sp.) clams.

A number of tubiculous polychaetes are often associated with geoduck beds (Goodwin and Pease 1987). This association was found on Lines 6, 7, and 21 in the form of mats of chaetopterid tube worms (*Phyllochaetopterus prolifica* and *Spiochaetopterus costarum*).

Macroalgae was observed when suitable hard substrate was present. Kelp beds consisting of *Nereocystis* luetkeana or ribbon kelps (e.g., *Laminaria saccharina*) were not found on any survey line. However, inshore of Lines 6 and 7 and within the City of Edmonds Underwater Park, a marine protected area, stands of kelp were seen. As noted earlier, the geoduck survey did not extend into this park. A substantial bed of foliose red algae (Rhodophyta) occurred on the offshore portions of Lines 6 and 7. This bed included a variety of species, but was dominated by *Botryoglossum* sp. (tentative identification and not confirmed). These plants are attached to chaetopterid worm tubes rather than gravel or large sediment particles.

Sea cucumbers (*Parastichopus californicus*) and Dungeness crabs (*Cancer magister*) were occasionally encountered during the survey. Both species were uncommon to rare in relative abundance and highly patchy in their distribution. Only on Line 7 was more than one Dungeness crab seen. On this line, 11 adult crabs were sighted in 3 transects. Crabs were usually seen only as they were running away. Based on these observations and from previous studies, scuba diving surveys are not an appropriate method for estimating crab population density (Kyte 1994a, b).

Gaper clams were counted at the same time as geoducks. However, descriptive statistics and statistical analysis of these data aside from an arithmetical average abundance would not be valid because of their highly variable and patchy distribution (Figure 10) (Table 2 in Appendix A). In addition, the count data on gapers likely does not have a statistically normal distribution. Thus, statistics for individual sub areas are not presented.

Only on Line 13 were a substantial number of gapers found (Figure 10) (Table 2 in Appendix A). The average number of gapers encountered in transects throughout the study area was 0.025 gapers/m^2 (0.002/ft^2).

3.6. Geoduck Sample Population Density

When the survey was restarted in April, the show factor study demonstrated that the geoducks had recovered from winter dormancy and were feeding vigorously. Observations within the two show plots declined with each examination as expected and show factors of 0.82 and 0.83 were determined in the north and south plots, respectively (Table 3 in Appendix A).

As specified by WDFW, sufficient transects were placed in the survey area to achieve a Coefficient of Variation (CV) (Formula 6) for population density estimates of less than 30 percent. Within the study area, an overall CV of 8.8 was obtained (Table 3). CVs for the individual sub areas are available in Table 3.

Table 2
Associated Marine Benthic Species in the MOSS Geoduck Survey Study Area

Group/Species[1]	Scientific Name
Sea lettuce (green algae)	*Ulva* sp.
Foliose red algae	Rhodophyta
Filamentous red algae	Rhodophyta
Rockweed (brown algae)	*Fucus* sp.
Burrowing anemone	*Pachycerianthus fimbriatus*
Hydroids	Cnidaria: Hydrozoa
Sea anemone	*Metridium* sp.
Sea anemone	*Urticina columbiana*
Baetic dwarf olive snail	*Olivella baetica*
Diamond back tritonia	*Tritonia festiva*
Rosy tritonia	*Tritonia diomedea*
Gaper clams (formerly horse clam)	*Tresus* sp.
Geoduck clam	*Panopea abrupta*
Rough mya clam	*Panomya* sp.
Truncate softshell clam	*Mya truncata*
Nuttall cockle	*Clinocardium nuttallii*
Northern horsemussel	*Modiolus modiolus*
Squid	*Rossia pacifica*
Hermit crab	*Pagurus* sp.
Red rock crab	*Cancer productus*
Dungeness crab	*Cancer magister*
Graceful rock crab	*Cancer gracilis*
Northern kelp crab	*Pugettia producta*
Tube worm	*Phyllochaetopterus prolifica*
Tube worm	*Spiochaetopterus costarum*
Seastar	*Pycnopodia helianthoides*
Seastar	*Dermasterias imbricata*
Seastar	*Mediaster aequalis*
Seastar	*Crossaster papposus*
Seastar	*Luidia foliata*
Seastar	*Solaster dawsoni*
Seastar	*Pisaster orchraceus*
Seastar	*Pisaster brevispinus*
Seastar	*Evasterias troschelli*
Brittlestar	*Ophiura luetkini*
Sea cucumber	*Parastichopus californicus*
English sole	*Pleuronectes vetulus*
C-O sole	*Pleuronichthys coenosus*
Buffalo sculpin	*Enophyrs bison*
Spotted ratfish	*Hydrologus colliei*

[1] Common names of molluscs, crustaceans, and fish are standardized by the American Fisheries Society

Table 3
Geoduck Population Density Statistics for the MOSS Study Area and Sub Areas, April 2002
(All estimates are number of geoducks per square meter [per square foot])

Statistic	Sub Area		C	All Lines
	A	B		
Number of Transects	56	17	67	140
Mean Density	1.00 (0.09)	0.43 (0.04)	0.80 (0.07)	0.84 (0.08)
Standard Error of the Mean Density	0.09 (0.01)	0.11 (0.01)	0.13 (0.01)	0.07 (0.01)
Coefficient of Variance of Density	9.47	24.76	15.60	8.76
95 % Confidence Interval	0.19 (0.02)	0.21 (0.02)	0.25 (0.02)	0.14 (0.01)

Note: All population numbers are estimates adjusted with an estimated show factor. The average show factor (2 estimates) used for all calculations was 0.83.

The CV specification by WDFW (Bradbury et al. 2000) translates to approximately one transect for every 1.2 hectares (ha) (3 acres) or 0.33 transects per 0.4 ha (1 acre) in areas covering more than 40.5 ha (100 acres) (Bradbury et al. 2000). According to a GIS map (Figure 2), the study area contained approximately 210 hectares (ha) (518 acres) between –6.1 m (20 ft) and –21.3 m (70 ft) MLLW. Within this area, 140 transects were examined giving a ratio of 1 transect per 1.5 ha (3.7 acres) or 0.27 transects per 0.4 ha (1 acre).

Geoducks were ubiquitous within the study area between – 21.3 m (70 ft) MLLW and the lower edge of the eelgrass (average depth = –5.6 m (18.4 ft) MLLW) (Table 4 in Appendix A). Because of the widespread occurrence of eelgrass in the study area, only Line 12 extended above – 5.5 m (18 ft) MLLW. On this line, geoducks were not found above – 5.5 m (18 ft) MLLW. Line 12 is a good example of the ubiquitous nature of the geoduck distribution. In spite of the highly unstable habitat in this zone, geoduck densities were relatively high ($1.35/m^2$ [$0.13/ft^2$]) between – 21.3 m (70 ft) MLLW and – 6.1 m (20 ft) MLLW.

Relative density was highest in Sub Area A north of the Edmonds Ferry Terminal (Table 3) (Table 4 in Appendix A). The lowest density was in Sub Area C between Point Edwards and Point Wells (Figure 11). Figure 12, a map produced using GIS mapping, illustrates the distribution of geoduck density.

The adjusted count data from the sub areas were tested for statistical significance using a single factor analysis of variance (ANOVA). This test showed that the three sub areas are not significantly different in population density ($F = 3.00$, $p = 0.053$).

The data showed that geoduck population density increases with depth (Figure 13, Table 4). Because of this trend, the correlation of population density and depth was tested. The following three categories were used following previous studies by WDFW (Goodwin and Pease 1991):

- Less than 9.1 m (30 ft)
- 9.1 m (30 ft) to 13.7 m (45 ft)
- Greater than 13.7 m (45 ft)

Because of the fact that strip transects lay across depth contours, it is not practical to examine the geoduck count data in smaller depth increments. Additionally, if smaller depth increments were used, the resultant analysis would not be comparable to WDFW published information.

Table 4
Geoduck Population Density Statistics by Depth Category for the Entire MOSS Geoduck Study Area. April 2002

Statistic	Depth Range		
	<9.1 m (30 ft)	**9.1 m to 13.7 m (45 ft)**	**> 13.7 m**
Number of Transects	47	35	55
Mean Density	0.20 (0.02)	0.90 (0.08)	1.37 (0.13)
Standard Error of the Mean Density	0.05 (0.00)	0.10 (0.01)	0.13 (0.01)
Coefficient of Variance of Density	22.99	10.66	9.86
95 % Confidence Interval around the Mean Density	0.09 (0.01)	0.19 (0.02)	0.26 (0.02)

Note: All population numbers are estimates adjusted with an estimated show factor. The average show factor (2 estimates) used for all calculations was 0.83.

There was only a weak correlation between density and depth ($r = 0.56$). However, densities among the three depth ranges were significantly different ($F = 33.0$, $p < 0.001$). Goodwin and Pease (1991) also found this direct relation to depth.

3.7. Geoduck Biomass Estimation

A total of 110 geoducks from 22 sample locations were collected, weighed, and measured to estimate the geoduck biomass within the study area (Tables 5 and 6 in Appendix A). Information on two parameters was obtained through this sampling; first, the range of individual geoduck weight by location and depth range was documented. Second, biomass, or weight per unit area (i.e., kilograms per hectare), was determined for the study area.

The heaviest geoducks were taken from Edwards Point and the lightest in Sub Area A (Table 5) (Table 5 in Appendix A). The geoduck samples from the sub areas were tested for statistical significance first using a single factor ANOVA. This test showed that geoduck individual weight was significantly different across the three sub areas ($F = 5.35$, $p = 0.0061$). In addition, because the sample sizes from the three sub areas was drastically unequal (Table 5), the data from sub areas A and C, which had similar sample sizes was tested for significant difference using a Student' T test. Geoduck weights in Sub Area A were significantly different than weights in Sub Area C (two tailed test $T = 1.98$, $p = 0.0078$).

When mean geoduck weight distribution within the study area was examined by depth, a trend of decreasing weight with depth was seen (Table 6, Figure 15). Both this study and that of Goodwin and Pease (1991) found that mean geoduck weight decreases with depth while population density increases. Within the study area, geoduck weight was significantly different across the three depth categories ($F = 12.29$, $p < 0.001$).

Because of the difference in population densities, the greatest biomass per unit area was at Point Wells with the lowest between Point Wells and Edwards Point (Table 5, Figure 14).

Shell length was also measured and found, as expected, strongly correlated (r = 0.81) with individual weight. Geoducks with the smallest average length were collected in Sub Area A north of the ferry terminal with the largest from the vicinity of Point Edwards, Sub Area C (Table 5) (Table 5 in Appendix A). The smallest individual geoducks were found on Line 6 in Sub Area A, while the largest were collected on Line 14 in Sub Area C near Point Edwards (Tables 5 and 6 in Appendix A).

Table 5
Geoduck Weight, Biomass, and Length Statistics for the MOSS Study Area and Sub Areas, April 2002

(All weights in kilograms (kg) (pounds [lbs])) Statistic	Sub Area			All Lines
	A	B	C	
Number of Geoducks Weighed	40	5	65	110
Mean Weight	0.92 (2.03)	1.36 (2.99)	1.13 (2.48)	1.06 (2.34)
Standard Error of the Mean Weight	0.06 (0.14)	0.16 (0.34)	0.04 (0.10)	0.04 (0.08)
Coefficient of Variance of Weight	6.72	11.51	3.99	3.5
95 % Confidence Interval	0.12 (0.27)	0.31 (0.68)	0.09 (0.19)	0.07 (0.16)
Mean Biomass kg/ha (lbs/acre)	9,216 (7965)	5,839 (5,216)	9,005 (7,567)	8,920 (8,154)
Mean Length (mm) (inches)	87.10 (3.43)	146.10 (5.75)	107.30 (4.22)	143.90 (5.7)
Standard Error of the Mean Length	3.24 (0.13)	5.39 (0.21)	2.05(0.08)	1.82 (0.07)
Coefficient of Variance of the Length	2.39	3.34	1.39	1.3
95% Confidence Interval around the Mean Length	6.35 (0.25)	10.57 (0.42)	4.01 (0.16)	3.56 (0.14)

Table 6
Geoduck Weight, Biomass, and Length Statistics by Depth Category for the Entire MOSS Geoduck Study Area. April 2002

(All weights in kilograms (kg) (pounds [lbs])) Statistic	Depth Range		
	< 9.1 m (30 ft)	9.1 m to 13.7 m (45 ft)	> 13.7 m
Number of Geoducks Weighed	36	39	35
Mean Weight	1.25 (2.7)	1.10 (2.4)	0.84. (1.8)
Standard Error of the Mean Weight	0.06 (0.15)	0.07 (0.14)	0.05 (0.10)
Coefficient of Variance of Weight	5.40	5.59	5.40
95 % Confidence Interval around the Mean Weight	0.13 (0.29)	0.12 (0.25)	0.09 (0.20)
Mean Biomass kg/ha (lbs/acre),	2,616 (2,393)	9,973 (8,419)	11,443 (10,428)
Mean Length (mm) (inches)	153.65 (6.05)	144.32 (5.68)	133.29 (5.25)
Standard Error of the Mean Length	2.84 (0.11)	3.37 (0.13)	2.29 (0.09)
Coefficient of Variance of the Length	1.85	2.34	1.72
95% Confidence Interval around the Mean Length	5.56 (0.22)	6.35 (0.25)	4.55 (0.18)

3.8. Extrapolation of Results to – 27.4 m (90 ft) MLLW

After the survey was completed, WDNR expressed an interest in geoduck population parameters between -70 ft MLLW and -90 ft MLLW. The main reasons the -70 ft limit was chosen was for diver safety and the -70 ft MLLW is the lower limit for commercial harvest. As noted in sections 3.6 and 3.7, statistically significant differences in density and weight were observed among depths. However, no data are available that describe the relationship between -70 and -90 ft MLLW for density and weight in this survey area. Due to the fact that density and weight differences occur between -70 and -90 ft MLLW, it is not possible to accurately extrapolate the results from this survey to estimate the density at -90 ft MLLW (Sizemore 2002). Neither WDFW nor WDNR routinely extrapolate density data across depth contours due to these observed differences (Sizemore 2002; Palazzi 2002). In order to obtain accurate data at the -90 ft depth, divers must actually survey these depths.

It must be noted that the above statement by King County was based on conversations with WDNR and WDFW personnel, to which Golder Associates Inc. was not privy.

3.9. Brightwater Outfall Zones

The four candidate marine outfall zones discussed in the Introduction were superimposed on the grid line and strip transect sampling design. The zones were located as shown on Figures 1 and 2. Each contained conditions representative of the sub area in which they were located.

Geoduck density is apparently highest in Zone 5 and lowest in Zone 7N, but the zones are not significantly different in population density ($F = 1.34$, $p = 0.27$).

4.0 CONCLUSIONS

The geoduck survey demonstrated that geoducks are nearly ubiquitous throughout the study area between the lower edge of the eelgrass and -21.3 m (70 ft) MLLW (Figure 12). The following points summarize the 2002 Geoduck Population Survey results:

- The average density of geoducks within the study area is 0.84 geoducks/m² (0.08/ft²) and did not vary significantly across the study area.
- Geoduck population density significantly increases with depth with the greatest density in the lowest depth range surveyed.
- The average geoduck weight was 1.1 kg (2.3 lbs) and varied significantly across the study area.
- The mean geoduck biomass in the study area was 8,920 kg/ha (8,154 lbs/acre).
- The greatest mean geoduck biomass (weight per unit area) is in Sub Area C south of Point Wells with the lowest also in Sub Area C, but north of Point Wells.
- Individual geoduck weight decreases significantly by depth with the lowest mean weight in the lowest depth range surveyed.
- Historical data does not exist and data were not gathered in this survey with which to extrapolate geoduck density and biomass trends beyond –21.3 m (70 ft) MLLW.
- The smallest (i.e., shortest) geoducks were found in Sub Area A and the largest to the south of Edwards Point in Sub Area C. No effect of area or substrate was seen, likely because of the relative homogeneity of the study area.
- There is no statistically significant difference in density among candidate outfall zones.
- The biota of the study area appeared to be typical of Central Puget Sound according to the experience of the surveyors and the presence of characteristic species.

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Appendix A

Data Tables

Line Positions and Measurements

	Line 1				Line 2			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 49 46.2	N47 49 41.4	--	N47 49 41.4	N47 49 41.7	N47 49 38.3	N47 49 36.6	N47 49 35.7
Longitude[1]	W122 22 22.2	W122 22 12.6	--	W122 22 12.6	W122 22 32.6	W122 22 28.0	W122 22 19.5	W122 22 17.2
Northing (ft)	306357	305859	--	305859	305916	305565	305382	305287
Easting (ft)	1262297	1262943	--	1262943	1261579	126886	1262462	1262618
Northing (m)	93378	93226	--	93226	93243	93136	93080	93051
Easting (m)	384748	384945	--	384945	384530	38675	384798	384846
Depth (ft)	65	33	--	20	72	34	19	10
Depth (m)	19.8	10.1	--	6.1	21.9	10.4	5.8	3.0
Date	4/11	4/11	--	4/11	4/11	4/18	4/18	4/18
Time	9:08	14:30	--	14:57	10:42	9:00	15:59	16:22
	Totals				**Totals**			
Number of Transects	--	--	--	6	--	--	--	10
Total Line Length (ft)	--	--	--	900	--	--	--	1500
Total Line Length (m)	--	--	--	274.3	--	--	--	457.2
	Line 3				**Line 4**			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 49 35.9	N47 49 29.6	--	N47 49 29.6	N47 49 27.4	N47 49 22.3	--	N47 49 21.5
Longitude[1]	W122 22 45.4	W122 22 24.4	--	W122 22 24.4	W122 22 57.9	W122 22 49.4	--	W122 22 39.4
Northing (ft)	305346	304679	--	304679	304502	303974	--	303879
Easting (ft)	1260694	1262114	--	1262114	1259824	1260394	--	1261074
Northing (m)	93069	92866	--	92866	92812	92651	--	92622
Easting (m)	384260	384692	--	384692	383994	384168	--	384375
Depth (ft)	70	43	--	10	66	43	--	17
Depth (m)	21.3	13.1	--	3.0	20.1	13.1	--	5.2
Date	4/18	4/19	--	4/19	4/22	4/22	--	4/23
Time	9:53	12:57	--	13:51	14:54	13:21	--	15:12
	Totals				**Totals**			
Number of Transects	--	--	--	11	--	--	--	11
Total Line Length (ft)	--	--	--	1650	--	--	--	1650
Total Line Length (m)	--	--	--	502.9	--	--	--	502.9

[1] Lat/Long are in ^{o}/m/s

Line Positions and Measurements

	Line 5				Line 6			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 49 23.6	N47 49 16.7	--	N47 49 16.7	N47 49 13.7	N47 49 06.5	--	N47 49 04.0
Longitude[1]	W122 23 04.3	W122 22 46.7	--	W122 22 46.7	W122 23 16.8	W122 23 07.6	--	W122 23 03.7
Northing (ft)	304126	303403	--	303403	303140	302398	--	302140
Easting (ft)	1259380	1260566	--	1260566	1258507	1259120	--	1259381
Northing (m)	92698	92477	--	92477	92397	92171	--	92092
Easting (m)	383859	384221	--	384221	383593	383780	--	383859
Depth (ft)	69	41	--	17	64	--	--	27
Depth (m)	21.0	12.5	--	5.2	19.5	--	--	8.2
Date	4/19	4/19	--	4/19	4/19	--	--	4/19
Time	10:05	14:17	--	14:59	8:53	--	--	12:07
	Totals				**Totals**			
Number of Transects	--	--	--	10	--	--	--	7
Total Line Length (ft)	--	--	--	1500	--	--	--	1050
Total Line Length (m)	--	--	--	457.2	--	--	--	320.0

	Line 7				Line 8			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 48 58.2	--	--	N47 48 54.8	N47 48 46.9	N47 48 46.8	--	N47 48 45.7
Longitude[1]	W122 23 19.5	--	--	W122 23 08.9	W122 23 26.6	W122 23 19.1	--	W122 23 14.3
Northing (ft)	301574	--	--	301215	300439	300419	--	300301
Easting (ft)	1258291	--	--	1259007	1257783	1258295	--	1258620
Northing (m)	91920	--	--	91810	91574	91568	--	--
Easting (m)	383527	--	--	383745	383372	383528	--	--
Depth (ft)	63	--	--	31	70	--	--	19
Depth (m)	19.2	--	--	9.4	21.3	--	--	5.8
Date	4/25	--	--	4/25	4/25	--	--	4/25
Time	10:08	--	--	10:48	9:03	--	--	11:37
	Totals				**Totals**			
Number of Transects	--	--	--	6	--	--	--	6
Total Line Length (ft)	--	--	--	900	--	--	--	900
Total Line Length (m)	--	--	--	274.3	--	--	--	274.3

Line Positions and Measurements

	Line 9				**Line 10**			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 48 46.4	--	--	N47 48 41.6	N47 48 37.4	--	--	--
Longitude[1]	W122 23 26.5	--	--	W122 23 19.6	W122 23 28.7	--	--	--
Northing (ft)	300388	--	--	299892	299480	--	--	--
Easting (ft)	1257789	--	--	1258250	1257620	--	--	--
Northing (m)	91558	--	--	91407	91282	--	--	--
Easting (m)	383374	--	--	383515	383323	--	--	--
Depth (ft)	68	--	--	24	73	--	--	34
Depth (m)	20.7	--	--	7.3	22.3	--	--	10.4
Date	4/22	--	--	4/22	4/8	--	--	4/8
Time	11:22	--	--	11:58	15:42	--	--	15:52
	Totals				**Totals**			
Number of Transects	--	--	--	4	--	--	--	1
Total Line Length (ft)	--	--	--	600	--	--	--	150
Total Line Length (m)	--	--	--	182.9	--	--	--	45.7
	Line 11				**Line 12**			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 48 31.1	--	--	N47 48 30.1	N47 48 18.0	--	--	N47 48 17.2
Longitude[1]	W122 23 38.4	--	--	W122 23 36.9	W122 23 54.0	--	--	W122 23 50.0
Northing (ft)	298855	--	--	298751	297549	--	--	297463
Easting (ft)	1256945	--	--	1257046	1255854	--	--	1256125
Northing (m)	91091	--	--	91059	90693	--	--	90667
Easting (m)	383117	--	--	383148	382784	--	--	382867
Depth (ft)	70	--	--	8	70	--	--	12
Depth (m)	21.3	--	--	2.4	21.3	--	--	3.7
Date	4/22	--	--	4/22	4/22	--	--	4/22
Time	9:46	--	--	9:55	8:42	--	--	9:20
	Totals				**Totals**			
Number of Transects	--	--	--	1	--	--	--	2
Total Line Length (ft)	--	--	--	150	--	--	--	300
Total Line Length (m)	--	--	--	45.7	--	--	--	91.4

Line Positions and Measurements

	Line 13				Line 14			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 48 12.0	--	--	N47 48 13.7	N47 48 03.4	--	--	N47 48 02.9
Longitude[1]	W122 23 56.0	--	--	W122 23 51.8	W122 24 03.5	--	--	W122 23 58.3
Northing (ft)	296944	--	--	297111	296083	--	--	296026
Easting (ft)	1255705	--	--	12255995	1255175	--	--	1255529
Northing (m)	90509	--	--	90559	90246	--	--	90229
Easting (m)	382739	--	--	3735627	382577	--	--	382685
Depth (ft)	74	--	--	6	70	--	--	13
Depth (m)	22.6	--	--	1.8	21.3	--	--	4.0
Date	4/17	--	--	4/17	4/22	--	--	4/22
Time	13:27	--	--	13:49	10:19	--	--	12:41
	Totals				**Totals**			
Number of Transects	--	--	--	3	--	--	--	3
Total Line Length (ft)	--	--	--	450	--	--	--	450
Total Line Length (m)	--	--	--	137.2	--	--	--	137.2
	Line 15				**Line 16**			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 47 53.0	--	--	N47 47 54.1	N47 47 42.1	--	--	N47 47 43.2
Longitude[1]	W122 24 07.1	--	--	W122 23 59.5	W122 24 03.7	--	--	W122 23 58.5
Northing (ft)	295035	--	--	295136	293926	--	--	294030
Easting (ft)	1254908	--	--	1255429	1255118	--	--	1255475
Northing (m)	89927	--	--	89957	89589	--	--	89620
Easting (m)	382496	--	--	382655	382560	--	--	382669
Depth (ft)	68	--	--	7	70	--	--	16
Depth (m)	20.7	--	--	2.1	21.3	--	--	4.9
Date	4/25	--	--	4/25	4/25	--	--	4/25
Time	12:20	--	--	12:40	14:12	--	--	14:34
	Totals				**Totals**			
Number of Transects	--	--	--	4	--	--	--	3
Total Line Length (ft)	--	--	--	600	--	--	--	450
Total Line Length (m)	--	--	--	182.9	--	--	--	137.2

TABLE 1

Line Positions and Measurements

	Line 17				Line 18			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 47 33.6	--	--	N47 47 34.3	N47 47 27.6	--	--	N47 47 29.0
Longitude[1]	W122 23 58.6	--	--	W122 23 50.1	W122 23 54.5	--	--	W122 23 46.3
Northing (ft)	293058	--	--	293117	292444	--	--	292575
Easting (ft)	1255448	--	--	1256030	1255716	--	--	1256278
Northing (m)	89324	--	--	89342	89137	--	--	89177
Easting (m)	382661	--	--	382838	382742	--	--	382914
Depth (ft)	63	--	--	10	70	--	--	14
Depth (m)	19.2	--	--	3.0	21.3	--	--	4.3
Date	4/25	--	--	4/25	4/8	--	--	4/8
Time	15:03	--	--	15:21	13:50	--	--	14:44
	Totals				**Totals**			
Number of Transects	--	--	--	4	--	--	--	5
Total Line Length (ft)	--	--	--	600	--	--	--	750
Total Line Length (m)	--	--	--	182.9	--	--	--	228.6
	Line 19				**Line 20**			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 47 19.2	N47 47 21.2	--	N47 47 18.3	N47 47 11.3	N47 47 12.5	N47 47 12.4	N47 47 13.2
Longitude[1]	W122 23 59.0	W122 23 48.1	--	W122 23 39.1	W122 23 59.8	W122 23 50.6	W122 23 43.7	W122 23 39.9
Northing (ft)	291600	291787	--	291481	290800	290909	290890	2900965
Easting (ft)	1255391	1256140	--	1256748	1255320	1255951	1256422	1256683
Northing (m)	88880	88937	--		88636	88669	88663	884214
Easting (m)	382643	382871	--	383057	382622	382814	382957	383037
Depth (ft)	66	--	--	15	68	--	--	12
Depth (m)	20.1	--	--	4.6	20.7	--	--	3.7
Date	4/23	--	--	4/23	4/23	--	--	4/23
Time	10:25	--	--	11:34	9:17	--	--	13:00
	Totals				**Totals**			
Number of Transects	--	--	--	7	--	--	--	9
Total Line Length (ft)	--	--	--	1050	--	--	--	1350
Total Line Length (m)	--	--	--	320.0	--	--	--	411.5

Line Positions and Measurements

	Line 21				Line 22			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 47 04.3	N47 47 03.2	--	N47 47 02.2	N47 46 42.9	--	--	N47 46 45.2
Longitude[1]	W122 23 55.1	W122 23 47.1	--	W122 23 43.2	W122 23 58.0	--	--	W122 23 53.4
Northing (ft)	290085	289962	--	289856	287921	--	--	288148
Easting (ft)	1255627	1256171	--	1256435	1255385	--	--	1255704
Northing (m)	88418	88380	--	88348	87758	--	--	87828
Easting (m)	382715	382881	--	382961	382641	--	--	382739
Depth (ft)	67	--	--	19	70	--	--	14
Depth (m)	20.4	--	--	5.8	21.3	--	--	4.3
Date	4/18	--	--	4/18	4/18	--	--	4/18
Time	11:57	--	--	13:43	14:46	--	--	15:20
	Totals				**Totals**			
Number of Transects	--	--	--	6	--	--	--	3
Total Line Length (ft)	--	--	--	900	--	--	--	450
Total Line Length (m)	--	--	--	274.3	--	--	--	137.2
	Line 23				**Line 24**			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 46 32.9	N47 46 36.9	--	N47 46 36.5	N47 46 24.5	--	--	N47 46 25.7
Longitude[1]	W122 24 01.3	W122 23 54.6	--	W122 23 53.7	W122 23 52.0	--	--	W122 23 49.4
Northing (ft)	286912	287308	--	287267	286049	--	--	286167
Easting (ft)	1255139	1255605	--	1255665	1255757	--	--	1255934
Northing (m)	87451	87571	--	87559	87188	--	--	87224
Easting (m)	382566	382708	--	382727	382755	--	--	382809
Depth (ft)	70		--	19	68	--	--	3
Depth (m)	21.3	0.0	--	5.8	20.7	--	--	0.9
Date	4/23	--	--	4/23	4/18	--	--	4/18
Time	8:09	--	--	11:56	8:20	--	--	8:34
	Totals				**Totals**			
Number of Transects	--	--	--	5	--	--	--	2
Total Line Length (ft)	--	--	--	750	--	--	--	300
Total Line Length (m)	--	--	--	228.6	--	--	--	91.4

Line Positions and Measurements

	Line 25				Line 26			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 46 14.3	N47 46 13.8	--	N47 46 14.2	N47 46 01.5	N47 46 01.8	--	N47 46 04.9
Longitude[1]	W122 23 55.3	W122 23 48.6	--	W122 23 46.7	W122 23 41.8	W122 23 39.9	--	W122 23 33.3
Northing (ft)	285020	284960	--	284998	283704	283732	--	284037
Easting (ft)	1255510	1255967	--	1256097	1256406	1256536	--	1256993
Northing (m)	86874	86856	--	86867	86473	86482	--	86574
Easting (m)	382679	382819	--	382858	382953	382992	--	383131
Depth (ft)	68	36	--	16	64	55	--	16
Depth (m)	20.7	11.0	--	4.9	19.5	16.8	--	4.9
Date	4/17	4/17	--	4/17	4/9	4/9	--	4/9
Time	8:47	11:56	--	12:10	10:11	13:04	--	13:58
	Totals				Totals			
Number of Transects	--	--	--	5	--	--	--	5
Total Line Length (ft)	--	--	--	750	--	--	--	750
Total Line Length (m)	--	--	--	228.6	--	--	--	228.6
	SHOW FACTOR PLOT NORTH				SHOW FACTOR PLOT SOUTH			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 49 44.0	--	--	--	N47 46 04.2	--	--	--
Longitude[1]	W122 22 22.4	--	--	--	W122 23 41.9	--	--	--
Northing (ft)	306135	--	--	--	283978	--	--	--
Easting (ft)	1262280	--	--	--	1256404	--	--	--
Northing (m)	93310	--	--	--	86556	--	--	--
Easting (m)	384743	--	--	--	382952	--	--	--
Depth (ft)	45	--	--	40	48	--	--	42
Depth (m)	13.7	--	--	12.2	14.6	--	--	12.8
Date	4/8	--	--	4/12	4/8	--	--	4/17
Time	12:15	--	--	9:10	10:19	--	--	10:24
	Totals				Totals			
Number of Transects	--	--	--	1	--	--	--	1
Total Line Length (ft)	--	--	--	150	--	--	--	150
Total Line Length (m)	--	--	--	45.7	--	--	--	45.7

Line Positions and Measurements

	ALIGNMENT 6				ALIGNMENT 7 NORTH			
	Start	Intermediate	Intermediate	Stop	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 48 19.3	--	--	N47 48 19.4	N47 47 36.8	--	--	N47 47 39.1
Longitude[1]	W122 23 52.7	--	--	W122 23 49.9	W122 24 00.8	--	--	W122 23 56.6
Northing (ft)	297679	--	--	297685	293385	--	--	293612
Easting (ft)	1255945	--	--	1256136	1255305	--	--	1255596
Northing (m)	90733	--	--	90734	89424	--	--	89493
Easting (m)	382812	--	--	382870	382617	--	--	382706
Depth (ft)	71	--	--	8	58	--	--	15
Depth (m)	21.6	--	--	2.4	17.7	--	--	4.6
Date	4/29	--	--	4/29	4/30	--	--	4/30
Time	11:05	--	--	11:32	11:45	--	--	12:05
	Totals				**Totals**			
Number of Transects	--	--	--	2	--	--	--	2
Total Line Length (ft)	--	--	--	300	--	--	--	300
Total Line Length (m)	--	--	--	91.4	--	--	--	91.4

	ALIGNMENT 7 SOUTH			
	Start	Intermediate	Intermediate	Stop
Latitude[1]	N47 46 38.7	--	--	N47 46 39.2
Longitude[1]	W122 23 59.5	--	--	W122 23 55.8
Northing (ft)	287498	--	--	287543
Easting (ft)	1255274	--	--	1255527
Northing (m)	87629	--	--	87643
Easting (m)	382608	--	--	382685
Depth (ft)	72	--	--	14
Depth (m)	21.9	--	--	4.3
Date	4/29	--	--	4/29
Time	13:20	--	--	13:55
	Totals			
Number of Transects	--	--	--	2
Total Line Length (ft)	--	--	--	300
Total Line Length (m)	--	--	--	91.4

-- Indicates that data were not recorded or the table cell and parameter are not appropriate

Counts of Gapers, Sea Cucumbers, and Dungness Crab from the MOSS Geoduck Study Area

Line Number	Corrected Depth (ft)	Gapers	Sea Cucumber	Dungeness Crab
1	23 to 19	9	0	0
1	27 to 23	0	0	0
1	33 to 27	1	0	0
1	39 to 32	0	0	0
1	48 to 39	1	0	0
1	65 to 48	7	0	0
2	14 to 10	0	0	0
2	19 to 14	0	0	0
2	40 to 35	1	0	0
2	49 to 40	1	0	0
2	60 to 49	0	0	0
2	71 to 60	0	0	0
3	12 to 10	0	0	0
3	12 to 12	0	0	0
3	20 to 12	0	0	0
3	24 to 20	0	0	0
3	30 to 24	0	0	0
3	34 to 30	0	0	1
3	43 to 34	0	0	0
3	50 to 44	6	0	0
3	56 to 50	13	0	0
3	63 to 56	3	0	0
3	70 to 63	0	0	0
4	19 to 17	0	0	0
4	21 to 19	0	0	0
4	25 to 21	0	0	0
4	29 to 25	0	0	0
4	32 to 29	7	0	0
4	39 to 34	6	0	0
4	43 to 39	7	0	0
4	46 to 41	4	0	0
4	57 to 46	6	0	0
4	66 to 57	8	0	0
5	20 to 17	0	0	0
5	25 to 20	0	0	0
5	29 to 25	0	0	0
5	34 to 29	1	0	0
5	40 to 34	0	0	0
5	45 to 40	1	0	0
5	53 to 41	0	0	0
5	57 to 53	0	0	0
5	63 to 57	0	0	0
5	69 to 63	0	0	0
6	31 to 27	0	0	0
6	34 to 31	2	0	0
6	40 to 34	1	0	0
6	48 to 40	0	2	0
6	55 to 48	0	0	0
6	61 to 55	0	0	0
6	64 to 61	0	0	0
7	31	0	0	1

Counts of Gapers, Sea Cucumbers, and Dungness Crab from the MOSS Geoduck Study Area

Line Number	Corrected Depth (ft)	Gapers	Sea Cucumber	Dungeness Crab
7	36 to 31	0	0	5
7	40 to 36	0	0	5
7	45 to 40	0	0	0
7	53 to 45	0	0	0
7	63 to 53	0	1	0
8	32 to 19	3	0	0
8	42 to 32	2	0	0
8	49 to 43	1	0	0
8	58 to 49	0	0	0
8	66 to 58	0	0	0
8	70 to 66	0	0	0
9	42 to 24	0	0	2
9	52 to 42	0	0	3
9	59 to 51	1	0	0
9	68 to 59	0	0	0
10	72 to 34	2	0	0
11	70 to 8	5	0	0
12	20 to 12	0	0	0
12	70 to 20	32	0	0
13	14 to 6	1	0	0
13	37 to 14	43	0	0
13	74 to 37	21	0	0
14	19 to 13	0	0	0
14	43 to 19	13	0	0
14	70 to 44	12	0	0
15	21 to 7	0	0	0
15	42 to 21	0	0	1
15	53 to 42	0	0	0
15	68 to 53	0	0	0
16	29 to 16	0	0	0
16	50 to 29	0	0	0
16	70 to 50	0	0	0
17	14 to 10	0	0	0
17	21 to 14	0	0	1
17	33 to 21	0	0	1
17	63 to 33	0	0	0
18	14	0	0	0
18	17 to 14	0	0	0
18	23 to 17	0	0	0
18	44 to 23	0	0	0
18	70 to 44	3	0	0
19	to 17	0	0	0
19	17 to 15	0	0	0
19	19 to 17	0	0	0
19	26 to 19	0	0	0
19	32 to 26	0	0	0
19	44 to 32	0	0	0
19	66 to 44	3	1	0
20	19 to 12	0	0	0
20	22 to 19	0	0	0
20	27 to 22	0	0	0
20	32 to 27	0	0	0
20	37 to 32	0	0	0
20	43 to 37	0	0	0
20	50 to 43	0	0	0
20	57 to 50	0	0	0
20	68 to 57	2	0	0

Counts of Gapers, Sea Cucumbers, and Dungness Crab from the MOSS Geoduck Study Area

Line Number	Corrected Depth (ft)	Gapers	Sea Cucumber	Dungeness Crab
21	30 to 19	2	0	0
21	48 to 30	2	0	1
21	49 to 48	0	0	2
21	59 to 49	0	0	0
21	67 to	1	0	0
21	to 59	1	0	0
22	17 to 14	1	0	0
22	34 to 17	6	0	0
22	70 to 34	0	0	0
23	24 to 26	0	0	0
23	27 to 19	0	0	0
23	31 to 24	0	0	0
23	46 to 31	0	0	0
23	70 to 46	2	0	0
24	31 to 3	0	0	0
24	68 to 31	0	0	0
25	24 to 16	0	0	0
25	36 to 24	0	0	0
25	41 to 33	0	0	0
25	62 to 41	0	0	0
25	68 to 55	0	0	0
26	24 to 16	1	0	0
26	35 to 24	0	0	0
26	44 to 35	0	0	0
26	55 to 44	0	0	0
26	64 to 56	1	0	0
Alignment 7N	33 to 15	0	0	0
Alignment 7N	58 to 33	0	0	0
Alignment 7S	39 to 14	0	0	0
Alignment 7S	72 to 39	29	0	0
Alignment 6	30 to 8	0	0	0
Alignment 6	71 to 30	13	0	0

Show Plot Data

Plot ID	Show Plot North		Show Plot South	
Location[1]	W122 22 22.4	N47 49 44.0	W122 23 41.9	N47 46 04.2
Location[2]	93310 m (306135 ft)	384743 m (1262280 ft)	86556 m (283978 ft)	382952 m (1256404 ft)
Corrected Depth	12.2 to 13.7 m MLLW (40 to 45 ft)		12.8 to 14.6 m MLLW (42 to 48 ft)	
Counts	Left	Right	Left	Right
First	55	74	43	59
Second	18	5	12	4
Third	2	4	2	1
Fourth	0	0	1	0
Totals	75	83	58	64
Overall Total	158		122	
Show Factor	0.82		0.84	

[1]Lat/Long are in o/m/s [2]Northing/Easting. Total area is 83.6 m^2 (900 ft^2) per plot.

Geoduck Count Raw Data by Grid Line and Strip Transect

Line Number	Corrected Depth ft	Raw counts Number of Siphons	Number of Siphons	Total /Transect[1]	Adjusted Total	Adjusted Total per m² (ft²)
1	65 to 48	42	47	89	107.2	1.28 (0.12)
1	48 to 39	45	45	90	108.4	1.3 (0.12)
1	39 to 32	49	30	79	95.2	1.14 (0.11)
1	33 to 27	37	29	66	79.5	0.95 (0.09)
1	27 to 23	8	9	17	20.5	0.24 (0.02)
1	23 to 19	5	4	9	10.8	0.13 (0.01)
2	71 to 60	37	56	93	112.0	1.34 (0.12)
2	60 to 49	48	47	95	114.5	1.37 (0.13)
2	49 to 40	50	65	115	138.6	1.66 (0.15)
2	40 to 35	54	32	86	103.6	1.24 (0.12)
2	19 to 14	5	3	8	9.6	0.12 (0.01)
2	14 to 10	4	0	4	4.8	0.06 (0.01)
3	70 to 63	48	36	84	101.2	1.21 (0.11)
3	63 to 56	56	78	134	161.4	1.93 (0.18)
3	56 to 50	63	50	113	136.1	1.63 (0.15)
3	50 to 44	55	29	84	101.2	1.21 (0.11)
3	43 to 34	52	55	107	128.9	1.54 (0.14)
3	34 to 30	71	53	124	149.4	1.79 (0.17)
3	30 to 24	23	23	46	55.4	0.66 (0.06)
3	24 to 20	19	25	44	53.0	0.63 (0.06)
3	20 to 12	5	4	9	10.8	0.13 (0.01)
3	12 to 12	0	0	0	0.0	0.00 (0.00)
3	12 to 10	0	0	0	0.0	0.00 (0.00)
4	66 to 57	9	6	15	18.1	0.22 (0.02)
4	57 to 46	90	78	168	202.4	2.42 (0.22)
4	46 to 41	70	62	132	159.0	1.9 (0.18)
4	43 to 39	28	23	51	61.4	0.73 (0.07)
4	39 to 34	44	37	81	97.6	1.17 (0.11)
4	32 to 29	32	40	72	86.7	1.04 (0.10)
4	29 to 25	32	38	70	84.3	1.01 (0.09)
4	25 to 21	9	5	14	16.9	0.2 (0.02)
4	21 to 19	1	0	1	1.2	0.01 (0.00)
4	19 to 17	0	0	0	0.0	0.00 (0.00)
5	69 to 63	13	10	23	27.7	0.33 (0.03)
5	63 to 57	72	78	150	180.7	2.16 (0.20)
5	57 to 53	67	48	115	138.6	1.66 (0.15)
5	53 to 41	83	88	171	206.0	2.46 (0.23)
5	45 to 40	80	74	154	185.5	2.22 (0.23)
5	40 to 34	37	42	79	95.2	1.14 (0.11)
5	34 to 29	25	31	56	67.5	0.81 (0.07)
5	29 to 25	26	34	60	72.3	0.86 (0.08)
5	25 to 20	9	12	21	25.3	0.30 (0.03)
5	20 to 17	1	2	3	3.6	0.04 (0.00)
6	64 to 61	40	45	85	102.4	1.22 (0.11)
6	61 to 55	47	54	101	121.7	1.46 (0.14)

Geoduck Count Raw Data by Grid Line and Strip Transect

Line Number	Corrected Depth ft	Raw counts Number of Siphons	Raw counts Number of Siphons	Total /Transect[1]	Adjusted Total	Adjusted Total per m² (ft²)
6	55 to 48	78	67	145	174.7	2.09 (0.19)
6	48 to 40	90	84	174	209.6	2.51 (0.23)
6	40 to 34	32	35	67	80.7	0.97 (0.09)
6	34 to 31	31	29	60	72.3	0.86 (0.08)
6	31 to 27	31	27	58	69.9	0.84 (0.08)
7	63 to 53	38	39	77	92.8	1.11 (0.10)
7	53 to 45	32	28	60	72.3	0.86 (0.08)
7	45 to 40	21	38	59	71.1	0.85 (0.08)
7	40 to 36	15	12	27	32.5	0.39 (0.04)
7	36 to 31	6	13	19	22.9	0.27 (0.03)
7	31	10	19	29	34.9	0.42 (0.04)
8	70 to 66	15	26	41	49.4	0.59 (0.05)
8	66 to 58	9	24	33	39.8	0.48 (0.04)
8	58 to 49	14	17	31	37.3	0.45 (0.04)
8	49 to 43	3	3	6	7.2	0.09 (0.01)
8	42 to 32	24	19	43	51.8	0.62 (0.06)
8	32 to 19	1	0	1	1.2	0.01 (0.00)
9	68 to 59	17	13	30	36.1	0.43 (0.04)
9	59 to 51	10	6	16	19.3	0.23 (0.02)
9	52 to 42	8	10	18	21.7	0.26 (0.02)
9	42 to 24	3	1	4	4.8	0.06 (0.01)
10	72 to 34	13	23	36	43.4	0.52 (0.05)
11	70 to 8	19	16	35	42.2	0.5 (0.05)
12	70 to 20	43	50	93	112.0	1.34 (0.12)
12	20 to 12	1	0	1	1.2	0.01 (0.00)
13	74 to 37	56	52	108	130.1	1.56 (0.14)
13	37 to 14	6	5	11	13.3	0.16 (0.01)
13	14 to 6	1	0	1	1.2	0.01 (0.00)
14	70 to 44	63	71	134	161.4	1.93 (0.18)
14	43 to 19	35	30	65	78.3	0.94 (0.09)
14	19 to 13	0	0	0	0.0	0.00 (0.00)
15	68 to 53	0	0	0	0.0	0.00 (0.00)
15	53 to 42	0	0	0	0.0	0.00 (0.00)
15	42 to 21	2	6	8	9.6	0.12 (0.01)
15	21 to 7	0	0	0	0.0	0.00 (0.00)
16	70 to 50	21	24	45	54.2	0.65 (0.06)
16	50 to 29	0	0	0	0.0	0.00 (0.00)
16	29 to 16	2	1	3	3.6	0.04 (0.00)
17	63 to 33	83	49	132	159.0	1.90 (0.18)
17	33 to 21	1	3	4	4.8	0.06 (0.01)
17	21 to 14	0	0	0	0.0	0.00 (0.00)
17	14 to 10	0	0	0	0.0	0.00 (0.00)
18	70 to 44	81	102	183	220.5	2.64 (0.24)
18	44 to 23	28	44	72	86.7	1.04 (0.10)
18	23 to 17	5	0	5	6.0	0.07 (0.01)

Geoduck Count Raw Data by Grid Line and Strip Transect

Line Number	Corrected Depth ft	Raw counts Number of Siphons	Raw counts Number of Siphons	Total /Transect[1]	Adjusted Total	Adjusted Total per m² (ft²)
18	17 to 14	1	2	3	3.6	0.04 (0.00)
18	14	0	2	2	2.4	0.03 (0.00)
19	66 to 44	122	98	220	265.1	3.17 (0.29)
19	44 to 32	67	66	133	160.2	1.92 (0.18)
19	32 to 26	18	15	33	39.8	0.48 (0.04)
19	26 to 19	9	6	15	18.1	0.22 (0.02)
19	19 to 17	3	5	8	9.6	0.12 (0.01)
19	17	0	0	0	0.0	0.00 (0.00)
19	17 to 15	0	0	0	0.0	0.00 (0.00)
20	68 to 57	71	51	122	147.0	1.76 (0.16)
20	57 to 50	77	69	146	175.9	2.10 (0.20)
20	50 to 43	58	56	114	137.3	1.64 (0.15)
20	43 to 37	55	50	105	126.5	1.51 (0.14)
20	37 to 32	43	33	76	91.6	1.10 (0.10)
20	32 to 27	32	14	46	55.4	0.66 (0.06)
20	27 to 22	7	10	17	20.5	0.24 (0.02)
20	22 to 19	3	3	6	7.2	0.09 (0.10)
20	19 to 12	2	3	5	6.0	0.07 (0.01)
21	67	5	2	7	8.4	0.10 (0.01)
21	59	57	53	110	132.5	1.59 (0.15)
21	59 to 49	59	37	96	115.7	0.38 (0.13)
21	49 to 48	23	17	40	48.2	0.58 (0.05)
21	48 to 30	3	4	7	8.4	0.10 (0.01)
21	30 to 19	1	0	1	1.2	0.01 (0.00)
22	70 to 34	79	104	183	220.5	2.64 (0.24)
22	34 to 17	15	31	46	55.4	0.66 (0.06)
22	17 to 14	3	1	4	4.8	0.06 (0.01)
23	70 to 46	0	0	0	0.0	0.00 (0.00)
23	46 to 31	7	10	17	20.5	0.24 (0.02)
23	31 to 24	47	42	89	107.2	1.28 (0.12)
23	24 to 26	3	4	7	8.4	0.10 (0.01)
23	27 to 19	3	3	6	7.2	0.09 (0.01)
24	68 to 31	10	7	17	20.5	0.24 (0.02)
24	31 to 3	0	0	0	0.0	0.00 (0.00)
25	68 to 55	41	39	80	96.4	1.15 (0.11)
25	62 to 41	32	40	72	86.7	1.04 (0.10)
25	41 to 33	30	27	57	68.7	0.82 (0.08)
25	36 to 24	11	11	22	26.5	0.32 (0.03)
25	24 to 16	2	2	4	4.8	0.06 (0.01)
26	64 to 56	103	108	211	254.2	3.04 (0.28)
26	55 to 44	63	69	132	159.0	1.90 (0.18)
26	44 to 35	60	55	115	138.6	1.66 (0.15)
26	35 to 24	13	16	29	34.9	0.42 (0.04)
26	24 to 16	0	1	1	1.2	0.01 (0.00)
align 6	71 to 30	68	67	135	162.7	1.95 (0.18)

Geoduck Count Raw Data by Grid Line and Strip Transect

Line Number	Corrected Depth ft	Raw counts		Total /Transect[1]	Adjusted Total	Adjusted Total per m² (ft²)
		Number of Siphons	Number of Siphons			
align 6	30 to 8	12	5	17	20.5	0.24 (0.02)
align 7 s	72 to 39	213	157	370	445.8	5.33 (0.50)
align 7 s	39 to 14	28	34	62	74.7	0.89 (0.08)
algin 7 n	58 to 33	48	51	99	119.3	1.43 (0.13)
align 7 n	33 to 15	1	0	1	1.2	0.01 (0.00)

1Total area is 83.6 m2 (900 ft2) per Transect

[2]unassigned zone

Geoduck Weight and Length Raw Data

Line Number	Collection Date	Corrected Depth m (ft)	Weight g (lbs)	Length mm (in)	Grading Photo Number (Append. B)
1	9-May	17.1 (56)	975 (2.1)	139.7 (5.5)	P5090087
1	9-May	17.1 (56)	930 (2.1)	134.3 (5.3)	P5090086
1	9-May	17.1 (56)	775 (1.7)	140.2 (5.5)	P5090087
1	9-May	17.1 (56)	1120 (2.5)	136.1 (5.4)	P5090087
1	9-May	17.1 (56)	1145 (2.5)	135.1 (5.3)	P5090087
2	10-May	18.6 (61)	885 (2.0)	133.4 (5.3)	P5100098
2	10-May	18.6 (61)	500 (1.1)	120.1 (4.7)	P5100098
2	10-May	18.6 (61)	935 (2.1)	136.1 (5.4)	P5100098
2	10-May	18.6 (61)	535 (1.2)	111.1 (4.4)	P5100098
2	10-May	18.6 (61)	510 (1.1)	117.5 (4.6)	P5100098
3	9-May	9.4 (31)	1155 (2.5)	146.3 (5.8)	P5090088
3	9-May	9.4 (31)	765 (1.7)	138.3 (5.4)	P5090088
3	9-May	9.4 (31)	1585 (3.5)	149.1 (5.9)	P5090088
3	9-May	9.4 (31)	1205 (2.7)	155.7 (6.1)	P5090088
3	9-May	9.4 (31)	1245 (2.7)	152.0 (6.0)	P5090088
4	10-May	7.9 (26)	1085 (2.4)	146.8 (5.8)	P5100102
4	10-May	7.9 (26)	1395 (3.1)	161.9 (6.4)	P5100102
4	10-May	7.9 (26)	865 (1.9)	131.3 (5.2)	P5100102
4	10-May	7.9 (26)	755 (1.7)	137.9 (5.4)	P5100102
4	10-May	7.9 (26)	1575 (3.5)	155.4 (6.1)	P5100102
5	9-May	7.6 (25)	1225 (2.7)	175.7 (6.9)	P5090090
5	9-May	7.6 (25)	1050 (2.3)	155.3 (6.1)	P5090089
5	9-May	7.6 (25)	1040 (2.3)	144.8 (5.7)	P5090090
5	9-May	7.6 (25)	1755 (3.9)	156.5 (6.2)	P5090090
5	9-May	7.6 (25)	1780 (3.9)	167.0 (6.6)	P5090090
5	10-May	16.5 (54)	775 (1.7)	149.0 (5.9)	P5100100
5	10-May	16.5 (54)	625 (1.4)	126.4 (5.0)	P5100100
5	10-May	16.5 (54)	680 (1.5)	135.5 (5.3)	P5100100
5	10-May	16.5 (54)	375 (0.8)	109.6 (4.3)	P5100100
5	10-May	16.5 (54)	395 (0.9)	111.0 (4.4)	P5100100
6	10-May	14.6 (48)	595 (1.3)	108.1 (4.3)	P5100101
6	10-May	14.6 (48)	335 (0.7)	98.9 (3.9)	P5100101
6	10-May	14.6 (48)	430 (0.9)	101.2 (4.0)	P5100101
6	10-May	14.6 (48)	245 (0.5)	87.1 (3.4)	P5100101
6	10-May	14.6 (48)	445 (1.0)	103.0 (4.1)	P5100101
7	10-May	12.8 (42)	1155 (11.55)	150.2 (5.9)	P5100099
7	10-May	12.8 (42)	1075 (2.4)	150.9 (5.9)	P5100099
7	10-May	12.8 (42)	630 (1.4)	118.7 (4.7)	P5100099
7	10-May	12.8 (42)	1245 (2.7)	155.2 (6.1)	P5100099
7	10-May	12.8 (42)	1070 (2.4)	144.7 (5.7)	P5100099
13	9-May	14.0 - 18.9 (46 - 62)	1565 (3.5)	167.7 (6.6)	P5090081
13	9-May	14.0 - 18.9 (46 - 62)	1845 (4.1)	175.7 (6.9)	P5090081
13	9-May	14.0 - 18.9 (46 - 62)	1110 (2.4)	146.1 (5.8)	P5090081
13	9-May	14.0 - 18.9 (46 - 62)	980 (2.2)	152.4 (6.0)	P5090081
13	9-May	14.0 - 18.9 (46 - 62)	1290 (2.8)	166.2 (6.5)	P5090081
14	9-May	7.9 (26)	2345 (5.2)	178.5 (7.0)	P5090085

Geoduck Weight and Length Raw Data

Line Number	Collection Date	Corrected Depth m (ft)	Weight g (lbs)	Length mm (in)	Grading Photo Number (Append. B)
14	9-May	7.9 (26)	1420 (3.1)	166.7 (6.6)	P5090085
14	9-May	7.9 (26)	1195 (2.6)	150.7 (5.9)	P5090085
14	9-May	7.9 (26)	1375 (3.0)	143.7 (5.7)	P5090085
14	9-May	7.9 (26)	1315 (2.9)	169.5 (6.7)	P5090085
14	9-May	13.1 (43)	1175 (2.6)	166.5 (6.6)	P5090084
14	9-May	13.1 (43)	1180 (2.6)	164.1 (6.5)	P5090081
14	9-May	13.1 (43)	1175 (2.6)	157.5 (6.2)	P5090081
14	9-May	13.1 (43)	1910 (4.2)	146.3 (5.8)	P5090081
14	9-May	13.1 (43)	1150 (2.5)	150.4 (5.9)	P5090081
16	10-May	16.2 (53)	975 (2.1)	148.6 (5.9)	P5100103
16	10-May	16.2 (53)	815 (1.8)	129.4 (5.1)	P5100103
16	10-May	16.2 (53)	740 (1.6)	120.7 (4.8)	P5100103
16	10-May	16.2 (53)	820 (1.8)	129.8 (5.1)	P5100103
16	10-May	16.2 (53)	1450 (3.2)	154.8 (6.1)	P5100103
18	8-May	5.2 - 8.2 (17 - 27)	1315 (2.9)	160.1 (6.3)	P5080076
18	8-May	5.2 - 8.2 (17 - 27)	1535 (3.4)	163.1 (6.4)	P5080076
18	8-May	5.2 - 8.2 (17 - 27)	2060 (4.5)	163.3 (6.4)	P5080076
18	8-May	5.2 - 8.2 (17 - 27)	1045 (2.3)	149.1 (5.9)	P5080076
18	8-May	5.2 - 8.2 (17 - 27)	1350 (3.0)	172.6 (6.8)	P5080076
18	8-May	12.5 - 13.4 (41 - 44)	1065 (2.3)	140.5 (5.5)	P5080075
18	8-May	12.5 - 13.4 (41 - 44)	1030 (2.3)	131.0 (5.2)	P5080075
18	8-May	12.5 - 13.4 (41 - 44)	1175 (2.6)	150.3 (5.9)	P5080075
18	8-May	12.5 - 13.4 (41 - 44)	1125 (2.5)	157.8 (6.2)	P5080075
18	8-May	12.5 - 13.4 (41 - 44)	1040 (2.3)	145.2 (5.7)	P5080075
18	8-May	19.5 (64)	635 (1.4)	117.5 (4.6)	P5080080
18	8-May	19.5 (64)	1000 (2.2)	143.3 (5.6)	P5080079
18	8-May	19.5 (64)	745 (1.6)	136.9 (5.4)	P5080080
18	8-May	19.5 (64)	620 (1.4)	107.3 (4.2)	P5080080
18	8-May	19.5 (64)	1515 (3.3)	113.0 (4.4)	P5080080
19	10-May	8.5 (28)	1405 (3.1)	163.4 (6.4)	P5100107
19	10-May	8.5 (28)	1205 (2.7)	147.9 (5.8)	P5100107
19	10-May	8.5 (28)	720 (1.6)	139.7 (5.5)	P5100107
19	10-May	8.5 (28)	1565 (3.5)	166.6 (6.6)	P5100107
19	10-May	8.5 (28)	1255 (2.8)	163.3 (6.4)	P5100107
20	10-May	8.8 (29)	1370 (3.0)	154.8 (6.1)	P5100106
20	10-May	8.8 (29)	525 (1.2)	120.2 (4.7)	P5100106
20	10-May	8.8 (29)	825 (1.8)	144.1 (5.7)	P5100106
20	10-May	8.8 (29)	795 (1.8)	124.8 (4.9)	P5100106
20	10-May	8.8 (29)	475 (1.0)	111.3 (4.4)	P5100106
22	8-May	6.4 (21)	1385 (3.1)	173.1 (6.8)	P5080074
22	8-May	6.4 (21)	1630 (3.6)	171.3 (6.7)	P5080074
22	8-May	6.4 (21)	1240 (2.7)	170.5 (6.7)	P5080074
22	8-May	6.4 (21)	1170 (2.6)	150.9 (5.9)	P5080074
22	8-May	6.4 (21)	1165 (2.6)	162.2 (6.4)	P5080074
22	8-May	12.5 (41)	915 (2.0)	142.7 (5.6)	P5080073
22	8-May	12.5 (41)	1185 (2.6)	150.9 (5.9)	P5080073

Geoduck Weight and Length Raw Data

Line Number	Collection Date	Corrected Depth m (ft)	Weight g (lbs)	Length mm (in)	Grading Photo Number (Append. B)
22	8-May	12.5 (41)	1350 (3.0)	155.4 (6.1)	P5080073
22	8-May	12.5 (41)	1425 (3.1)	161.2 (6.3)	P5080073
22	8-May	12.5 (41)	1445 (3.2)	150.3 (5.9)	P5080073
22	8-May	19.8 (65)	755 (1.7)	144.1 (5.7)	P5080067
22	8-May	19.8 (65)	575 (1.3)	131.7 (5.2)	P5080067
22	8-May	19.8 (65)	855 (1.9)	156.7 (6.2)	P5080067
22	8-May	19.8 (65)	615 (1.4)	122.3 (4.8)	P5080067
22	8-May	19.8 (65)	665 (1.5)	133.1 (5.2)	P5080067
25	10-May	10.7 (35)	1140 (2.5)	150.3 (5.9)	P5100104
25	10-May	10.7 (35)	1005 (2.2)	147.0 (5.8)	P5100104
25	10-May	10.7 (35)	825 (1.8)	139.1 (5.5)	P5100104
25	10-May	10.7 (35)	1455 (3.2)	154.4 (6.1)	P5100104
25	10-May	10.7 (35)	1330 (2.9)	148.0 (5.8)	P5100104
26	10-May	17.7 (58)	925 (2.0)	153.2 (6.0)	P5100105
26	10-May	17.7 (58)	1045 (2.3)	143.3 (5.6)	P5100105
26	10-May	17.7 (58)	655 (1.4)	122.8 (4.8)	P5100105
26	10-May	17.7 (58)	1000 (2.2)	150.4 (5.9)	P5100105
26	10-May	17.7 (58)	975 (2.1)	140.5 (5.5)	P5100105

Geoduck Biomass Sample Locations

Biomass Sample Number	Line Number	Corrected Depth (m/ft)		Average Weight (g/lbs)		Approximate Geographic Coordinates			
						Latitude (° m s N)	Longitude (° m s W)	Northing (ft)	Easting (ft)
1	1	17.1	56	989	2.2	47 49 46.2	122 22 22.2	306357	1262297
2	2	18.6	61	673	1.5	47 49 41.7	122 22 32.6	305916	1261579
3	3	9.4	31	1,191	2.6	47 49 29.6	122 22 24.4	304679	1262114
4	4	7.9	26	1,135	2.5	47 49 21.5	122 22 39.4	303879	1261074
5	5	7.6	25	1,370	3	47 49 16.7	122 22 46.7	303403	1260566
6	5	16.5	54	570	1.3	47 49 16.7	122 22 46.7	303403	1260566
7	6	14.6	48	410	0.9	47 49 06.5	122 23 07.6	302098	1259120
8	7	12.8	42	1,035	2.3	47 48 54.8	122 23 08.9	301215	1259007
9	13	14.0 - 18.9	46 - 62	1,358	3	47 48 12.0	122 23 56.0	296944	1255705
10	14	7.9	26	1,530	3.4	47 48 02.9	122 23 58.3	296026	1255529
11	14	13.1	43	1,318	2.9	47 48 03.4	122 24 03.5	296083	1255175
12	16	16.2	53	960	2.1	47 47 42.1	122 24 03.7	293926	1255118
13	18	5.2 - 8.2	17 - 27	1,461	3.2	47 47 29.0	122 23 46.3	292575	1256278
14	18	12.5 - 13.4	41 - 44	1,087	2.4	47 47 27.6	122 23 54.5	292444	1255716
15	18	19.5	64	903	2	47 47 27.6	122 23 54.5	292444	1255716
16	19	8.5	28	1,230	2.7	47 47 18.3	122 23 39.1	291481	1256748
17	20	8.8	29	798	1.8	47 47 12.4	122 23 43.7	290890	1256422
18	22	6.4	21	1,318	2.9	47 46 45.2	122 23 53.4	288148	1255704
19	22	12.5	41	1,264	2.8	47 46 42.9	122 23 58.0	287921	1255385
20	22	19.8	65	693	1.5	47 46 42.9	122 23 58.0	287921	1255385
21	25	10.7	35	1,151	2.5	47 46 13.8	122 23 48.6	284960	1255967
22	26	17.7	58	920	2	47 46 01.8	122 23 39.9	283732	1256536

Associated Marine Benthic Species in the MOSS Geoduck Survey Study Area

Group/Species[1]	Scientific Name
Sea lettuce (green algae)	*Ulva* sp.
Foliose red algae	Rhodophyta
Filamentous red algae	Rhodophyta
Rockweed (brown algae)	*Fucus* sp.
Burrowing anemone	*Pachycerianthus fimbriatus*
Hydroids	Cnidaria: Hydrozoa
Sea anemone	*Metridium* sp.
Sea anemone	*Urticina columbiana*
Baetic dwarf olive snail	*Olivella baetica*
Diamond back tritonia	*Tritonia festiva*
Rosy tritonia	*Tritonia diomedea*
Gaper clams (formerly horse clam)	*Tresus* sp.
Geoduck clam	*Panopea abrupta*
Rough mya clam	*Panomya* sp.
Truncate softshell clam	*Mya truncata*
Nuttall cockle	*Clinocardium nuttallii*
Northern horsemussel	*Modiolus modiolus*
Squid	*Rossia pacifica*
Hermit crab	*Pagurus* sp.
Red rock crab	*Cancer productus*
Dungeness crab	*Cancer magister*
Graceful rock crab	*Cancer gracilis*
Northern kelp crab	*Pugettia producta*
Tube worm	*Phyllochaetopterus prolifica*
Tube worm	*Spiochaetopterus costarum*
Seastar	*Pycnopodia helianthoides*
Seastar	*Dermasterias imbricata*
Seastar	*Mediaster aequalis*
Seastar	*Crossaster papposus*
Seastar	*Luidia foliata*
Seastar	*Solaster dawsoni*
Seastar	*Pisaster orchraceus*
Seastar	*Pisaster brevispinus*
Seastar	*Evasterias troschelli*
Brittlestar	*Ophiura luetkini*
Sea cucumber	*Parastichopus californicus*
English sole	*Pleuronectes vetulus*
C-O sole	*Pleuronichthys coenosus*
Buffalo sculpin	*Enophyrs bison*
Spotted ratfish	*Hydrologus colliei*

[1] Common names of molluscs, crustaceans, and fish are standardized by the American Fisheries Society

Appendix B
Geoduck Grading Information

Tulalip Tribes of Washington June 6, 2002
Shellfish Program
Michael E. McHugh
Shellfish Harvest Management Biologist

Geoduck Biomass Assessment – Edmonds Proposed STP (King County MOSS Project)
Commercial Assessment of Photographed Geoducks

Table 1. Comments on and Commercial Assessment of Geoduck Clams (*Panopea abrupta*) from Photographs Supplied by Golder & Associates for the Edmonds Area

Photograph Identification Number	Location of Clam in Photograph	Comments	Grade
P5080067	1	PS	2
	2	PS / B / S	3 / 4
	3	PS	2
	4		2
	5		2
P5080073	1	PS	2
	2	D	2
	3 – clam on side	D	2
	4	D	2
	5	D	2
P5080074	1	CS / LS	1
	2	CS / LS	1
	3	CS / LS	1
	4	L	2
	5	CS / LS	1
P5080075	1	CS / LS	1
	2	CS / LS	1
	3	PS / B	3 / 4
	4	CS / LS	1
	5	PS / PD	1 / 2
P5080076	1	L	3
	2	LS	1
	3	DM / DS	3
	4	DM / DS	3
	5	DM / DS	3
P5080077	1	L	2
	2	LS / CS	1
	3	DS	2
	4	DS	2
	5	DS	2
P5080080	1	L	2
P5080079 copy	2	Skinny Siphon	2

	3	Skinny Siphon	2
	4	Skinny Siphon	3
	5	L / CS / LS	1 / 2
P5090081	1	PD	2
	2	PD	2
	3	PS / US	3
	4	US (gray siphon)	3
	5	SS	2
P5090084	1	DS	2
	2	SS	3
	3	D	2
	4	PS / SS	3
	5	D	2
P5090085	1	CS / LS	1
	2	SS / Skinny Siphon	3
	3	SS / Skinny Siphon	3
	4	CS / LS	1
	5	D	2
P5090087	1	CS / LS	1
P5090086 COPY	2	CS / LS	1
	3	SS	3
	4	D	2
	5	D	2
P5090088	1	CS / LS	1
	2	CS / LS	1
	3	CS / LS	1
	4	CS / LS	1
	5	CS / LS	1
P5090090	1	L / DS	3
P5090089 COPY	2	DS	2
	3	CS / LS	1
	4	SS	2
	5	CS / LS	1
P5100098	1	PS	1
	2	PS	1
	3	PS	1
	4	D / Bullet	3 / 4
	5		1
P5100099	1	PS	2 / 3
	2		2 / 3
	3	SS / Bullet	3
	4		2
	5	PS / DS	3

P5100100	1	CS / LS	1
	2	CS / LS	1
	3	D	2
	4	PS	1
	5	PS	1
P5100101	1	D / Bullets	3 / 4
	2	D / Bullets	3 / 4
	3	D / Bullets	3 / 4
	4	D / Bullets	3 / 4
	5	D / Bullets	3 / 4
P5100102	1	PD	1 / 2
	2	PD	1 / 2
	3	SS	3
	4	SS	3
	5	DS	2
P5100103	1	CS / LS	1
	2	CS / LS	1
	3	CS / LS	1
	4	DS	2
	5	CS / LS	1
P5100104	1		3
	2	DM / A	3
	3		2
	4	PD	2
	5		2
P5100105	1	SS	2
	2		1
	3	Bullet	3 / 4
	4	DS / DM	2
	5	DS / Ugly shell	3
P5100106	1	Bullet	3 / 4
	2	PS sub 1.5 lbs	1
	3	Bullet	4
	4	PS sub 1.5 lbs	1
	5	PS sub 1.5 lbs	1
P5100107	1	DSiphon / Dshell	2
	2	DSiphon / Dshell	2
	3	DSiphon / Dshell	2
	4	DSiphon / Dshell	2
	5	DSiphon / Dshell	2

Tabled data is for individual clams in photographs supplied by Golder & Associates (Michael A. Kyte, Senior Marine Biologist) to the Tulalip Tribes Shellfish Program. Clams are numbered from one to five starting with the clam on the left and counting to the right. Comments on individual clam are included to support grades assessed and allow an understanding of the commercial grading scale used by Tulalip during commercial geoduck harvest activities. Comments are also included to compensate for slight variations of possible grades by Tulalip staff and harvesters with others in the commercial clam industry.

Michael McHugh and Vern Carpenter graded clams under blind response conditions with a third person (grade keeper) keeping notes. This method was used to confirm the correct calibration of Michael McHugh (Tulalip Shellfish Program Harvest Manager) with Vern Carpenter (Shellfish Buyer and Independent Tribal Shellfish Harvester) as well as maintain a degree of integrity through the grading system as a slight variation in grades could lead to large commercial value differences. Individual grades were nearly the same for all clams assessed (over 90% received the same score) and any clams not receiving matching grades were re-reviewed and assessed by both graders. Codes were developed to expedite the grading system and allow multiple comments per clam.

Codes
PS – Possible Small, clams smaller than 1.5 lbs may have reduced market value
D – Dark Skin or Dark Shell characteristics (M, mantele / S, shell)
SS – Short Siphon (necks) less than length of shell (valve)
CS – Clean Shell (valve) chalky-white in color, good quality
CN – Clean Neck (siphon) blonde or beige not dark brown or gray
LS – Long Siphon (neck) is greater than or equal to shell (valve) length when contracted
L – Lesions, irregular marks and or bumps upon the siphon
DM/A – Dark Mantle / Alligator condition of siphon or mantle that appears to be leathery
B – Bullet, stubby neck (siphon) and almost no meat outside or above the shell
U – Ugly, ugly siphon much like alligator but bent and not uniformly shaped

Not all clams look the same nor have the same physical characteristics that can be qualitatively measured. This qualitative difference lends itself to a slight problem in keeping clam grades consistent between parties and those not involved in the commercial industry. With this in mind, a brief qualitative scale has been developed to assist in the understanding of the market value of clams of this kind. Additionally, changes to the scale may occur as market conditions change with quality of product, time of year and quality of product already in the market place at any one time. The value and grade of the same clam will drop somewhat as the market gets flooded with product as is true of the inverse that the value of a marginal clams increase as the supply is reduced and higher quality product becomes limited in availability.

Definitions of Geoduck Clam Grading System
1- Clean siphon and clean white shell. No blemishes on siphon or shell from growing conditions or effects of harvesting. Clams may have two or three times siphon length compared to valve length when siphon in not contracted or semi-contracted. Siphon is equal to or greater than valve length when fully contracted and has uniform tapering of the siphon from shell to siphon tip. Color of siphon is light brown with smooth exterior skin having limited scars and or marks.

2 – Clam may have slightly shorter siphon and a slightly darker (brown or gray/black) coloration to siphon and or shell. Siphon will still be equal to and possible slightly longer than shell when contracted but coloration may exclude clam from a No. 1 grade. The clam may have a small degree of shell deformity and possible lesion like marks upon skin of the siphon. A No. 2 grade clam is very similar to a No. 1 but graded down mostly due to color and possibly length of siphon.

3 – Clams with off-color shells as well as off-colored siphons that posses shorter siphons that are equal to or less than the length of the shell. Clams may have multiple shell deformities due to growing conditions of rocky substrate or hardpan conditions. Clams may also have off-color shell and siphons from anaerobic growing conditions giving a blackish or oil-stained appearance. Clam siphon may have multiple lesions and or scars on the skin of the siphon to reduce grade. The clam may have a leathery appearance of the siphon and or mantle visible between valves or base of siphon. Rough skin of the siphon, rough siphon tip or growth on the siphon tip and smaller siphon in diameter than appears the shell could support are conditions of a No. 3 clam.

Bullets 3 / 4 – Some graders use only a one through three grading scale to grade product as does Tulalip with the exception of Bullets. Bullets are also referred to as hand grenades due to their football like appearance and lack of siphon length. The clam will have a fully developed shell and have almost no siphon visible greater than one or two inches for a six inch shell. Siphons less than half the shell length (fully contracted) are many times graded as bullets and sold at $0.50 per pound if purchased by the buyer at all. These many times become “take-home” clams and or bait for an supplemental fisheries such as crab due to the low market value yet quality as a food sources or bait. Hardpan growing conditions such as a clay layer 0.3 meters below the substrate will account for this condition as well as cobble gravel substrate conditions. Not very common to have slight variations in this grade as a bullet is a bullet.

The most recent market value of geoduck clams is listed below for what Tulalip harvesters encountered this spring. The price per pound for 1’s and 2’s was slightly depressed due to an unusually flooded market at the end of the 2001 – 02 commercial geoduck clam management period. Normal prices per pound for Tulalip product may be found at one or two dollars per pound higher during normal market conditions. A one time price per pound ex-vessel prices was reached in December 1996 for all product no grade at $10.00 per pound.

No. 1	$ 5.50 per pound
No. 2	$ 4.50 per pound
No. 3	$ 1.50 per pound
Bullets	$ 0.50 per pound

Photo ID: P5090086 and P5090087; Transect number: 1; Zone: unassigned;
Grade (left to right): 1, 1, 3, 2, 2

Photo ID: P5100098; Transect number: 2; Zone: unassigned;
Grade (left to right): 1, 1, 1, 3 / 4, 1

Photo ID: P5090088; Transect number: 3; Zone: unassigned;
Grade (left to right): 1, 1, 1, 1, 1

Photo ID: P5100102; Transect number: 4; Zone: 5;
Grade (left to right): 1 / 2, 1 / 2, 3, 3, 2

Photo ID: P5100100; Transect number: 5; Zone: 5;
Grade (left to right): 1, 1, 2, 1, 1

Photo ID: P5090089 and P5090090; Transect number: 5; Zone: 5;
Grade (left to right): 3, 2, 1, 2, 1

Photo ID: P5100101; Transect number: 6; Zone: 5;
Grade (left to right): 3 / 4, 3 / 4, 3 / 4, 3 / 4, 3 / 4

Photo ID: P5100099; Transect number: 7; Zone: 5;
Grade (left to right): 2 / 3, 2 / 3, 3, 2, 3

Photo ID: P5090081; Transect number: 13; Zone: 6;
Grade (left to right): 2, 2, 3, 3, 2

Photo ID: P5090084; Transect number: 14; Zone: 6;
Grade (left to right): 2, 3, 2, 3, 2

Photo ID: P5090085; Transect number: 14; Zone: 6;
Grade (left to right): 1, 3, 3, 1, 2

Photo ID: P5100103; Transect number: 16; Zone: 7 N;
Grade (left to right): 1, 1, 1, 2, 1

Photo ID: P5080075; Transect number: 18; Zone: 7 N;
Grade (left to right): 1, 1, 3 / 4, 1, 1 /2

Photo ID: P5080076; Transect number: 18; Zone: 7 N;
Grade (left to right): 3, 1, 3, 3, 3

Photo ID: P5080079 and P5080080; Transect number: 18; Zone: 7 N;
Grade (left to right): 2, 2, 2, 3, 1 / 2

Photo ID: P5100107; Transect number: 19; Zone: unassigned;
Grade (left to right): 2, 2, 2, 2, 2

Photo ID: P5100106; Transect number: 20; Zone: 7 S;
Grade (left to right): 3 / 4, 1, 4, 1, 1

Photo ID: P5080067; Transect number: 22; Zone: 7 S;
Grade (left to right): 2, 3 / 4, 2, 2, 2

Photo ID: P5080073; Transect number: 22; Zone: 7 S;
Grade (left to right, clam on side is middle): 2, 2, 2, 2, 2

Photo ID: P5080074; Transect number: 22; Zone: 7 S;
Grade (left to right): 1, 1, 1, 2, 1

Photo ID: P5100104; Transect number: 25; Zone: unassigned;
Grade (left to right): 3, 3, 2, 2, 2

Photo ID: P5100105; Transect number: 26; Zone: unassigned;
Grade (left to right): 2, 1, 3 / 4, 2, 3

Appendix C
Study Plan and Comments

STUDY PLAN FOR A SURVEY OF GEODUCK CLAMS AND OTHER MARINE BIOLOGICAL RESOURCES FOR THE KING COUNTY MOSS PROJECT IN THE POINT WELLS TO EDMONDS AREA

Prepared by

Michael A. Kyte
Senior Marine Biologist
Golder Associates Inc.

January 25, 2002

INTRODUCTION

King County plans to construct a new North Treatment Facility in northern King County or southern Snohomish County. The wastewater treatment plant will discharge effluent via a new outfall into Puget Sound waters offshore of northern King or southern Snohomish County.

The MOSS site selection team examined a study area for the proposed outfall that extends from Meadow Point, Seattle, in the south to the town of Mukilteo to the north. This study area contains a variety of features that will influence the location and design of the outfall. These features include biological features, geophysical features, in-water human structures (designated as community features), and submarine Model Toxics Control Act (MTCA) sites (designated as hazardous waste features). This Scope of Work will concentrate on biological features since the other aspects of the study area are being examined by other teams.

The study area includes a variety of biological habitats and communities. For example, eelgrass meadows (*Zostera* sp.) are prevalent. Many shoreline reaches provide areas suitable for baitfish (i.e., surf smelt and sandlance) spawning throughout the study area. Geoduck beds are ubiquitous in and below the nearshore area, which has been defined by the King County Nearshore Technical Committee[1] of Puget Sound. Geoduck beds are likely present in most, if not all of the sites.

The Washington Departments of Fish and Wildlife (WDFW), Natural Resources (WDNR), and Health (WDH) have concerns about geoducks (*Panopea abrupta*) in the

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[1] Williams, G.D., R.M. Thom, J.E. Starkes, J.S. Brennan, J. P. Houghton, D. Woodruff, P.L. Striplin, M. Miller, M. Pedersen, A. Skillman, R. Kropp, A. Borde, C. Freeland, K. McArthur, V. Fagerness, S. Blanton, and L. Blackmore. 2001. Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9). J.S. Brennan, Editor. Report prepared for King County Department of Natural Resources, Seattle, WA.

vicinity of any proposed outfall. Geoducks and other commercially important clams may be impacted directly by construction or indirectly by the release of wastewater from the outfall. It is because of these concerns that documentation of stocks prior to permitting and construction is required.

As part of King County's site selection and eventual permitting process for the outfall replacement, documentation of existing marine resources is necessary. This is particularly important in the case of the commercially important geoducks and ecologically sensitive habitat. Eelgrass beds and forage fish spawning habitat have been documented and mapped by other teams. King County's project manager, Randy Schuman and the County's prime consultant Parametrix, have requested Golder Associates Inc., to conduct a biological resource (bioresources) study to supplement existing information in the vicinity of the outfall sites with the highest priority. The results of the study will be used to evaluate impacts from outfall construction and operation on bioresources in the study area.

The bioresource study will include the following components:

- A quantitative delineation of geoduck resources.
- Documentation of the presence and relative abundance of associated biota including commercially important crabs and gaper or horse clams, and sensitive rockfish populations.
- Confirmation of the distribution of eelgrass (*Zostera marina*) in the study area.

GEODUCK STUDY PLAN

The purpose of this study is to assess geoduck and other bioresources that may be impacted by the proposed King County outfall. It should be noted that this survey is for the purpose of impact evaluation, natural resource damage assessment, and outfall site selection. In addition, it is likely that the information gathered in this survey can and will be used to support an Environmental Impact Statement, an Endangered Species Act (ESA) Section 7(c) Biological Assessment, and a description of and impact evaluation to Essential Fish Habitat. Because of these purposes, a more thorough assessment is required than if the survey was a pre-harvest assessment.

Study Area

For the purposes of this assessment, King County has designated the following sites as preferred locations for an outfall (Figure 1[2]):

Site 5

Site 5 is located just north of the Edmonds ferry terminal.

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[2] Figure 1 can be accessed as a *.pdf file at the following Internet site: ftp://external.golder.com/Seattle/Parametrix/geoduck/geoduckstudyarea2.pdf

There is limited biological information available from the nearshore mapping efforts by King County. Eelgrass and kelp beds are present in and adjacent to this site.

The Edmonds Underwater Park, a marine protected area established by the City of Edmonds is present along the southern edge of the site. Although not directly on the site, Edmonds ferry terminal and an existing outfall are located nearby and would be within the study area for the geoduck survey.

Site 6

Site 6 is located at Edwards Point south of the Edmonds Marina and includes a marine terminal formerly occupied by UnoCal.

Limited biological data on this site is available from the WDNR ShoreZone Inventory. Eelgrass is present but the density is unknown.

There is a marine protected area established by the City of Edmonds at the north end of the site and a major in-water structure (oil pier) located on the site.

Site 7N

Site 7N is located on the north side of Point Wells.

The nearshore area contains a broad expanse eelgrass and kelp beds in the southern portion.

There are no marine sanctuaries or in-water structures at the site.

Site 7S

Site 7S is located at Point Wells.

The nearshore has a mix of eelgrass species with varying densities. Most of the eelgrass is present at the southern end of the site.

There are no marine protected areas at this site. The Point Wells oil terminal and docks are located on the site.

Existing Information

The WDFW Geoduck Atlas for 2001[3] indicates the presence of two geoduck tracts (06000 and 06100) in the study area. Both have been surveyed by WDFW with the most recent surveys in 1980 on tract 06000 north of Edmonds. Both are considered by WDFW as not available for harvest because of numerous pollution sources.

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[3] Sizemore, B. and M. Ulrich. 2001. 2001 Geoduck Atlas: Atlas of Major Geoduck Tracts of Puget Sound. Washington Department of Fish and Wildlife. Annual Report Number FPA01-05.

In addition, a survey of habitats and bioresources was conducted in 1994[4] to assess alternatives for relocation of the Edmonds ferry terminal. This study found geoduck and gaper clams between the UnoCal pier and the south breakwater of the Edmonds Marina (MOSS area 6) with densities of approximately 2.6 per square meter (0.24 per square foot). In addition, a geoduck population estimate for the area between the existing ferry terminal and the north marina breakwater was 0.5 per square meter (0.04 per square foot).

Population Density Estimation

A quantitative geoduck survey will be conducted along the shoreline from south of Point Wells, site 7S, to north of Edmonds, site 5 (Figure 1). The geoduck survey will be extended approximately one half mile beyond sites 7S and 5 to ensure adequate coverage and to account for all geoduck stocks that may be decertified because of the presence of the outfall. The survey area extends along approximately 5 miles of shoreline (26,400feet) and includes approximately 605 acres between –80 feet MLLW and the lower edge of the intertidal zone. The study area is bounded by the following coordinates:

- North: 47°49.776'N Latitude, 122°22.224'W Longitude
- South: 47°46.314' N Latitude, 122°23.912'W Longitude

Survey methodology will follow protocols established by WDFW.[5] It is standard practice for WDFW geoduck surveys to be conducted using lines of "transects" approximately 1,000 feet apart within large areas (i.e., "tracts"). "Transects" as used by WDFW are plots or quadrats measuring 6 feet wide by 150 feet long containing 900 square feet. Sufficient transects are placed in a tract to achieve a level of variance of 30 percent or less as measured by the Coefficient of Variation. This specification usually translates into approximately one transect for every three acres or 0.33 transects per acre in areas covering more than 100 acres.

For the purposes of this study, the WDFW procedures will be slightly modified to use the metric system. Transects will be 50 meters (m) long and 2 m wide rather than 150 feet by 6 feet. This will facilitate estimating geoduck densities per square meter as requested by King County. This change has been approved by WDFW for use by Michael Kyte in previous surveys.

Consecutive transects will be examined by two qualified geoduck survey biologists using scuba equipment. The transects will be placed consecutively along a line extending between the upper and lower depth limits and examined from the deeper end up into shallow water because of diving safety considerations.

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[4] Pentec Environmental, Inc. 1995. Marine Resources in the Vicinity of Potential Washington Ferry Terminal Sites in Edmonds. Preliminary Report submitted to CH2M Hill. January 4, 1995.
[5] Bradbury, A. et al. 2000. Stock Assessment of Subtidal Geoduck Clams (*Panopea abrupta*) in Washington. Washington Department of Fish and Wildlife Marine Resources Unit.

Because of the relatively large area to be surveyed for the MOSS project, the spacing specified by WDFW will be used on the Point Wells to Edmonds shoreline. Thus, 27 transect lines will be examined from south of site 7S to north of site 5. The average length of the lines will be approximately 1,077 feet.

WDFW guidelines also state that WDFW geoduck surveys are conducted from –18 feet MLLW down to 70 feet salt water (fsw) depth as indicated on the survey diver's depth gauge. However, in the experience of Michael Kyte, WDFW and local Indian tribes usually want a geoduck survey that is conducted to evaluate impacts from an outfall to examine geoduck habitat from the lower edge of the intertidal zone (i.e., approximately –4 feet MLLW) down to –70 feet MLLW. The purpose of this extended depth range is to account for all potentially harvestable geoducks and gaper (*Tresus* sp.) clams. Thus, the depth range of this survey will be from –4 feet down to –70 feet MLLW.

During the examination of each transect, sediment type and associated biota will be noted. In addition to geoducks, special attention will also be paid to *Tresus* sp. (gaper clams), sensitive or "vulnerable" rockfish species (*Sebastes* sp.), and commercially harvestable crabs including Dungeness (*Cancer magister*), graceful (*C. gracilis*), and red rock (*C. productus*) crabs. The lower edge of eelgrass (*Zostera marina*) beds, macroalgae assemblages and substrates will also be noted. Observations will be recorded by depth and transect location to allow geographic documentation of conditions.

Table 1 lists the planned positions of the geoduck survey transect lines with proposed outfall alignments and biomass and tissue sampling locations (see following sections). These positions are illustrated in Figure 1.

A global positioning system (GPS) instrument with an accuracy of plus or minus 10 to 20 feet will be used to locate the transect lines and document positions of show plots, biomass samples (see following sections), and features of interest such as reefs or wrecks.

Outfall Alignment Construction Impact Evaluation

In addition to the transect lines examined during the geoduck survey, particular attention will be paid to proposed outfall alignments. It is along these corridors that direct impacts to geoducks and other bioresources and habitats would be realized. Because of the economic importance of geoducks and the fact that critical habitats for species listed under the ESA would be impacted, it is important that a precise assessment of habitats and bioresources be conducted along these alignments. Thus, in order to be assured that quantitative data are acquired on specified alignments, a precision underwater positioning system known as "Dive Tracker" (Desert Star Systems), will be employed. Using this system will allow the survey divers to follow a specified alignment with minimal horizontal error. The Dive Tracker will be used on the five alignments in area 6, 7N, and 7S (Figure 1). Geoducks, habitats, and other bioresources will be enumerated and distributions will be mapped for the final report and use in site selection and impact assessment.

Show Factor Study

In addition to a quantitative count of geoduck and associated biota, a study will be conducted to determine a season and area-specific show factor (the proportion of a geoduck population that can be accounted for through siphon counts). This study is planned in response to consistent direction from WDFW regarding surveys for outfall impact evaluation.[6] Because of the size of the survey area, two show factor plots will be established, one on each end of the survey area. They will be marked and monitored following WDFW protocols[2]. Details of the show factor study methods used and results obtained will be included in the final report on this survey.

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In addition to population density, information will be needed on the biomass of geoducks within the study area for natural resource damage assessment in monetary terms. In order to obtain these data, individual geoducks will be harvested and weighed following WDFW methods.

A stratified random statistical design will be used for sampling and data analysis. The transects as established and recorded from the population estimate, will be stratified according to depth range into the following strata:

- Shallow: -4 feet to –35 feet MLLW
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Harvest locations will be distributed throughout the study area by selecting every sixth transect as a potential collection point as prescribed by WDFW guidelines. Only those transects with geoduck population density at or above the threshold for commercial harvesting (0.04 geoducks per square foot) will be considered for harvesting[7].

The first five geoducks in each selected increment will be harvested using a water jet. Preliminary calculations of total transect line lengths and projecting the number of biomass sample sites indicates that approximately 150 to 200 geoducks will be harvested for the purpose of biomass estimation. However, sufficient number of geoducks will be harvested to achieve the 30 percent coefficient of variation prescribed by WDFW protocols.

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Geoducks cannot be returned to their habitat with a reasonable chance of survival. Also, care must be taken that the geoducks collected in the survey will not enter the public market as this area has not been certified for harvesting and the collected specimens cannot be included in fishery quotas or management plans. Thus, the geoducks will be donated to the Seattle Aquarium for research and display.

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King County, the sponsor for this study, has requested specimens for tissue chemical analysis. Thus, 18 geoducks will be harvested at specified locations (see Figure 1) and delivered to King County. A King County – selected laboratory will analyze whole and edible portions of these specimens for the following:

- Fecal coliform bacteria
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The data may also be used to determine human health risks associated with geoduck consumption. Results of this analysis will be reported in a separate document.

Schedule

WDFW guidelines specify that geoduck surveys must be conducted between March 1 and October 15. Geoducks can not be accurately counted outside of this window as they become dormant over the winter. March and April are some of the best months for geoduck surveys as the clams are vigorously feeding to restore losses suffered during dormancy over the winter. Thus, the bioresource and geoduck survey will begin on March 5, 2002 and should be completed in the same month. The survey with show factor and biomass studies will require approximately 15 to 20 working days.

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The survey divers will be led by Michael Kyte, senior marine biologist, and will include as a core team Dale Dickinson and Eric Parker from Golder Associates. These three divers are highly experienced and certified by WDFW for geoduck surveys. Mr. Kyte and Mr. Dickinson have conducted numerous geoduck surveys over the last 20 years, including five major studies in Kitsap and King County waters for wastewater outfalls in 1995 through 1999.

A fourth person from Golder Associates will also be used. WDFW guidelines indicate that a 4-person team is optimum for safety and efficient completion of surveys in larger areas. If the fourth person is not WDFW-certified, they will be trained and accompanied by either Michael Kyte or Dale Dickinson to ensure the accuracy of their counts. This practice has been approved for Michael Kyte by WDFW personnel in the past.

Report

A final report will contain the following:

- A description with appropriate maps of habitats, sediment types, transect locations, associated biota, geoduck, and sediment type distribution
- Positions of all transect lines, biomass and tissue sampling locations, and other features of interest (e.g., special habitats or cultural resources)
- Raw geoduck show and associated biota count data
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TULALIP SHELLFISH COMMENTS – 2/20/02
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STUDY PLAN FOR A SURVEY OF GEODUCK CLAMS AND OTHER MARINE BIOLOGICAL RESOURCES FOR THE KING COUNTY MOSS PROJECT IN THE POINT WELLS TO EDMONDS AREA

Prepared by

Michael A. Kyte
Senior Marine Biologist
Golder Associates Inc.

January 25, 2002

INTRODUCTION

King County plans to construct a new North Treatment Facility in northern King County or southern Snohomish County. The wastewater treatment plant will discharge effluent via a new outfall into Puget Sound waters offshore of northern King or southern Snohomish County.

The MOSS site selection team examined a study area for the proposed outfall that extends from Meadow Point, Seattle, in the south to the town of Mukilteo to the north. This study area contains a variety of features that will influence the location and design of the outfall. These features include biological features, geophysical features, in-water human structures (designated as community features), and submarine Model Toxics Control Act (MTCA) sites (designated as hazardous waste features). This Scope of Work will concentrate on biological features since the other aspects of the study area are being examined by other teams.

The study area includes a variety of biological habitats and communities. For example, eelgrass meadows (*Zostera* sp.) are prevalent. Many shoreline reaches provide areas suitable for baitfish (i.e., surf smelt and sandlance) spawning throughout the study area. Geoduck beds are ubiquitous in and below the nearshore area, which has been defined by the King County Nearshore Technical Committee[1] of Puget Sound. Geoduck beds are likely present in most, if not all of the sites.

The Washington Departments of Fish and Wildlife (WDFW), Natural Resources (WDNR), and Health (WDH) have concerns about geoducks (*Panopea abrupta*) in the vicinity of any proposed outfall (as do the Tulalip Tribes). Geoducks and other commercially important clams may be impacted directly by construction or indirectly by the release of wastewater from the outfall. It is because of these concerns that documentation of stocks prior to permitting and construction is required.

As part of King County's site selection and eventual permitting process for the outfall replacement, documentation of existing marine resources is necessary. This is particularly important in the case of the commercially important geoducks and ecologically sensitive habitat. Eelgrass beds and forage fish spawning habitat have been documented and mapped by other teams. King County's project manager, Randy Schuman and the County's prime consultant Parametrix, have requested Golder Associates Inc., to conduct a biological resource (bioresources) study to supplement existing information in the vicinity of the outfall sites with the highest priority. The results of the study will be used to evaluate impacts from outfall construction and operation on bioresources in the study area.

The bioresource study will include the following components:

- A quantitative delineation of geoduck resources. As well as a qualitative assessment of the resource. Due to the resource (geoduck) being grade sensitive in value a combination of standing biomass and commercial value is requested. This can be done by grading the geoducks individually prior to lab or aquarium delivery and is standard in Tulalip resource assessment.
- Documentation of the presence and relative abundance of associated biota including commercially important crabs and gaper or horse clams, and sensitive rockfish populations. Also, an impact assessment of the sport usage of this area for crab (see WDFW CRC data) and a potential related shift in user group effort as a result of the Brightwater facility to other shellfish management catch recording areas. Shrimp populations and critical habitat are also of importance for a full and viable assessment. Significant commercial value of shrimp is locked into this area and a full assessment of the population (standing) and the effects of an additional STP is expected.

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[1] Williams, G.D., R.M. Thom, J.E. Starkes, J.S. Brennan, J. P. Houghton, D. Woodruff, P.L. Striplin, M. Miller, M. Pedersen, A. Skillman, R. Kropp, A. Borde, C. Freeland, K. McArthur, V. Fagerness, S. Blanton, and L. Blackmore. 2001. Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9). J.S. Brennan, Editor. Report prepared for King County Department of Natural Resources, Seattle, WA.

- Confirmation of the distribution of eelgrass (*Zostera marina*) in the study area. More than confirmation of existing data from a shore region impacted by a rail line is needed. This entire beach and shallow-water community have been modified by the presence of the rail line and a higher level of eelgrass assessment than a confirmation is due – density and precise location for monitoring would be a good direction.

GEODUCK STUDY PLAN

The purpose of this study is to assess geoduck and other bioresources (please list or identify what is the complete suite of targeted species or resources) that may be impacted by the proposed King County outfall. It should be noted that this survey is for the purpose of impact evaluation, natural resource damage assessment, and outfall site selection. In addition, it is likely that the information gathered in this survey can and will be used to support an Environmental Impact Statement, an Endangered Species Act (ESA) Section 7(c) Biological Assessment, and a description of and impact evaluation to Essential Fish Habitat. Because of these purposes, a more thorough assessment is required than if the survey was a pre-harvest assessment.

Study Area

For the purposes of this assessment, King County has designated the following sites as preferred locations for an outfall (Figure 1[2]):

Site 5

Site 5 is located just north of the Edmonds ferry terminal.

There is limited biological information available from the nearshore mapping efforts by King County. Eelgrass and kelp beds are present in and adjacent to this site.

The Edmonds Underwater Park, a marine protected area established by the City of Edmonds is present along the southern edge of the site. Although not directly on the site, Edmonds ferry terminal and an existing outfall are located nearby and would be within the study area for the geoduck survey.

Site 6

Site 6 is located at Edwards Point south of the Edmonds Marina and includes a marine terminal formerly occupied by UnoCal.

Limited biological data on this site is available from the WDNR ShoreZone Inventory. Eelgrass is present but the density is unknown.

There is a marine protected area established by the City of Edmonds at the north end of the site and a major in-water structure (oil pier) located on the site.

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[2] Figure 1 can be accessed as a *.pdf file at the following Internet site:
ftp://external.golder.com/Seattle/Parametrix/geoduck/geoduckstudyarea2.pdf

Site 7N

Site 7N is located on the north side of Point Wells.

The nearshore area contains a broad expanse eelgrass and kelp beds in the southern portion.

There are no marine sanctuaries or in-water structures at the site.

Site 7S

Site 7S is located at Point Wells.

The nearshore has a mix of eelgrass species with varying densities. Most of the eelgrass is present at the southern end of the site.

There are no marine protected areas at this site. The Point Wells oil terminal and docks are located on the site.

Existing Information

The WDFW Geoduck Atlas for 2001[3] indicates the presence of two geoduck tracts (06000 and 06100) in the study area. Both have been surveyed by WDFW with the most recent surveys in 1980 on tract 06000 north of Edmonds. Both are considered by WDFW as not available for harvest because of numerous pollution sources. It should be noted that the resource guide is geoduck clam specific only. The data collected and presented in the atlas by WDFW is very limited and suspect by Tulalip in both location and density. The timing and effort of these jump dives and reconnaissance surveys allow some information but should not be viewed as reliable data beyond geoduck presence insights.

In addition, a survey of habitats and bioresources was conducted in 1994[4] to assess alternatives for relocation of the Edmonds ferry terminal. This study found geoduck and gaper clams between the UnoCal pier and the south breakwater of the Edmonds Marina (MOSS area 6) with densities of approximately 2.6 per square meter (0.24 per square foot). Tulalip would like a copy of this information if it is free for share, as well as comments on how this survey effort can be meshed with proposed assessments. In addition, a geoduck population estimate for the area between the existing ferry terminal and the north marina breakwater was 0.5 per square meter (0.04 per square foot).

Population Density Estimation

A quantitative geoduck survey will be conducted along the shoreline from south of Point Wells, site 7S, to north of Edmonds, site 5 (Figure 1). The geoduck survey will be

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[3] Sizemore, B. and M. Ulrich. 2001. 2001 Geoduck Atlas: Atlas of Major Geoduck Tracts of Puget Sound. Washington Department of Fish and Wildlife. Annual Report Number FPA01-05.
[4] Pentec Environmental, Inc. 1995. Marine Resources in the Vicinity of Potential Washington Ferry Terminal Sites in Edmonds. Preliminary Report submitted to CH2M Hill. January 4, 1995.

extended approximately one half mile beyond sites 7S and 5 to ensure adequate coverage and to account for all geoduck stocks that may be decertified because of the presence of the outfall. Expanding the assessment to the entire eastern shore of Puget Sound is suggested south from Meadow Point in Seattle to the edge of the Snohomish estuary or Port Gardner in the north. With the short sub-tidal bench area for the geoduck stocks to be located on (our estimates identify no more than 600 ft. per line or four WDFW transects) the added effort for investigation is not extreme or unjustified. This proposed project, coupled with other eastern shore projects that are being proposed, increases the level of impact to the entire region. Cumulative impact assessment needs to start with the baseline data collection and be focused on a regional habitat. Rail expansion and mitigation, ferry terminal modifications, marine protected area proposals and this project put an undue strain on this region that has limited information for habitat as well as background condition information. The survey area extends along approximately 5 miles of shoreline (26,400feet) and includes approximately 605 acres between –80 feet MLLW and the lower edge of the intertidal zone. The study area is bounded by the following coordinates:

- North: 47°49.776'N Latitude, 122°22.224'W Longitude
- South: 47°46.314' N Latitude, 122°23.912'W Longitude

Survey methodology will follow protocols established by WDFW.[5] It is standard practice for WDFW geoduck surveys to be conducted using lines of "transects" approximately 1,000 feet apart within large areas (i.e., "tracts"). "Transects" as used by WDFW are plots or quadrats measuring 6 feet wide by 150 feet long containing 900 square feet. Sufficient transects are placed in a geoduck tract to achieve a level of variance of 30 percent or less as measured by the Coefficient of Variation not a standard CV, may want to include the equation used by WDFW for survey confidence.. This specification usually translates into approximately one transect for every three acres or 0.33 transects per acre in areas covering more than 100 acres. Because the WDFW geoduck assessment method was developed for large generally flat tracts in south sound the spacing and effort are not ideal for habitats that are long and steep like the area proposed for study. WDFW suggests diving/swimming diagonal or obtuse lines to account for long and narrow tracts such as the area being proposed. This will maximize bottom-time yet sacrifice data positioning and has not been used for any pre-fishing tract assessment, personnel communication WDFW Bradbury 2001. I would like to see initial spacing of 1000 ft. so if needed 500 ft. intervals will be easy and standard with our work as well as WDFW's.

For the purposes of this study, the WDFW procedures will be slightly modified to use the metric system (please see above and convert the data at the end of the study). Transects will be 50 meters (m) long and 2 m wide rather than 150 feet by 6 feet (standard 900 ft. sq. requested for comparison with other state and tribal efforts). This

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[5] Bradbury, A. et al. 2000. Stock Assessment of Subtidal Geoduck Clams (*Panopea abrupta*) in Washington. Washington Department of Fish and Wildlife Marine Resources Unit.

will facilitate estimating geoduck densities per square meter as requested by King County. This change has been approved by WDFW for use by Michael Kyte in previous surveys. Although approved by WDFW in the past, keeping a standard – albeit arbitrary area for survey- is always a good idea when there are hundred or so of similar studies to compare to the new or supplementary effort. Additionally, no assessment of patch size to "transect" or quadrant has been conducted to allow the addition of a second quadrant size for data collection. I don't believe it is a big concern that data is collected by 900 ft sq or 900 ft sq plus 10% but the idea to stay with a reviewed and developed method is important.

Consecutive transects will be examined by two qualified geoduck survey biologists using scuba equipment. The transects will be placed consecutively along a line extending between the upper and lower depth limits and examined from the deeper end up into shallow water because of diving safety considerations. Deep to shallow may be problematic in data collection and marginally warranted by safety concerns. If enough time is allotted for diving the area can be done in a week or less with a four person crew – that is based on a near identical effort we did last summer along Whidbey Island tract 03900 Randle Point. All other biomass observations for other surveys have been conducted shallow to deep, commercial biomass estimates start deeper than the eelgrass line plus two vertical feet, deeper biomass estimates for forage fish considerations if spawning is in the area of the tract. With these considerations survey method direction may have some importance. With these habitats, starting at 32 ft fsw may only allow two quads ending at 68 ft fsw. Finding the 32 ft mark diving from shallow to deep is more likely than cutting the data out once the dive has gone deep to shallow and transect will need to be ended prior to the full 150 ft length. Experience from stream surveys has shown different habitat calls between upstream v. downstream efforts. This experience, as well as surveying from light to dark may be more effective than moving from dark to light.

Because of the relatively large area to be surveyed for the MOSS project, the spacing specified by WDFW will be used on the Point Wells to Edmonds shoreline. Thus, 27 transect lines will be examined from south of site 7S to north of site 5. The average length of the lines will be approximately 1,077 feet. Why 1,000 ft spacing is not used and a random starting point developed for one end of the area to be assessed.

WDFW guidelines also state that WDFW geoduck surveys are conducted from –18 feet MLLW down to 70 feet salt water (fsw) depth as indicated on the survey diver's depth gauge. However, in the experience of Michael Kyte, WDFW and local Indian tribes usually want a geoduck survey that is conducted to evaluate impacts from an outfall to examine geoduck habitat from the lower edge of the intertidal zone (i.e., approximately –4 feet MLLW) down to –70 feet MLLW. The purpose of this extended depth range is to account for all potentially harvestable geoducks and gaper (*Tresus* sp.) clams. Thus, the depth range of this survey will be from –4 feet down to –70 feet MLLW. This is an excellent idea as resources other than geoduck have been suggested for assessment. Concerns of missing important horse clam resources by the standard WDFW geoduck are of concern. Patches of horse may not be located or assessed as well as would be warranted by using a method developed for geoduck. This may drive the use for two methods one for shallow and one for deep clam populations with the line being at the commercial shallow cut-off depth. Bourne recently developed a grid based horse clam biomass method that would be potentially better in the shallow areas.

During the examination of each transect, sediment type (based on what soil or sediment scheme and is this surface and subsurface with anything quantitative) and associated biota will be noted. In addition to geoducks, special attention will also be paid to *Tresus* sp. (gaper clams) (are weight/dig samples proposed for horse or a standard weight used), sensitive or "vulnerable" rockfish species (*Sebastes* sp.), and commercially harvestable crabs including Dungeness (*Cancer magister*), graceful (*C. gracilis*), and red rock (*C. productus*) crabs. The lower edge of eelgrass (*Zostera marina*) beds, macroalgae assemblages and substrates will also be noted. Observations will be recorded by depth and transect location to allow geographic documentation of conditions.

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In addition to population density, information will be needed on the biomass of geoducks and horse clams within the study area for natural resource damage assessment in monetary terms. In order to obtain these data, individual geoducks and horse clams will be harvested and weighed following WDFW methods.

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The first five geoducks in each selected increment will be harvested using a water jet. Preliminary calculations of total transect line lengths and projecting the number of biomass sample sites indicates that approximately 150 to 200 geoducks will be harvested for the purpose of biomass estimation. However, sufficient number of geoducks will be harvested to achieve the 30 percent coefficient of variation prescribed by WDFW protocols.

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Collected geoducks will be weighed on the survey support vessel following WDFW guidelines. Biomass will be estimated as an average live wet weight including shell of an individual geoduck with a 95 percent confidence interval. We would like a table with location (lat / long), weight in grams and pounds, shell length, siphon length and grade. The grade is a bit qualitative but will be very important is the final economic value and Tulalip will assist in the grading of geoduck if needed. Since this outfall will limit the potential harvest of geoducks in the area the best valuation of the resource is needed.

Geoducks cannot be returned to their habitat with a reasonable chance of survival. Also, care must be taken that the geoducks collected in the survey will not enter the public market as this area has not been certified for harvesting and the collected specimens cannot be included in fishery quotas or management plans (not true as a bait fishery plan has been worked on for both geoduck and horse clam resources and harvesting could occur in as little as 15 days from a notice). Thus, the geoducks will be donated to the Seattle Aquarium for research and display.

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The report will be presented in paper and in electronic (*.pdf) formats for ease of use and copying as needed. All data files will be available as Micro Soft Excel spreadsheets and as GIS shape files.

TABLE 1						
MOSS Geoduck Sampling Positions						
Population Density Transect Lines						
Line Number	LENGTH(FT)	LENGTH(M)	Offshore Easting(X)	Offshore Northing(Y)	Offshore Longitude(X)	Offshore Latitude(Y)
1	1296.758	395.252	1262293.45241	306473.62661	122.3728602	47.82981673
2	1631.259	497.208	1261328.12470	305992.16880	122.3767502	47.82844409
3	1926.436	587.178	1260361.77838	305391.86341	122.3806344	47.82674551
4	2097.248	639.241	1259652.46932	304652.80868	122.3834608	47.82468071
5	2366.292	721.246	1259180.61747	304147.16409	122.3853397	47.82326872
6	2512.226	765.726	1258203.29767	303060.14417	122.3892278	47.82023521
7	2251.701	686.318	1258174.55133	302627.85190	122.3893092	47.81904874
8	1515.127	461.811	1257909.78799	301279.38107	122.3902757	47.81533804
9	851.858	259.646	1257721.46456	300357.29436	122.390966	47.81280025
10	135.652	41.347	1257636.78906	299450.22992	122.3912359	47.81030938
11	285.726	87.089	1256883.48442	298861.59714	122.3942524	47.80865415
12	216.151	65.883	1255854.25724	297576.49541	122.3983337	47.80507452
13	168.369	51.319	1255686.22217	296971.47666	122.3989672	47.80340685
14	480.626	146.495	1255137.50454	295908.49775	122.4011114	47.80046272
15	495.215	150.942	1254848.99302	294496.83144	122.402168	47.79657737
16	493.374	150.380	1254967.01640	293998.22354	122.4016466	47.79521734
17	611.282	186.319	1255289.84681	293152.05206	122.4002634	47.79291609
18	868.277	264.651	1255577.08209	292549.53555	122.3990452	47.79128068
19	1127.732	343.733	1255354.61263	291609.08891	122.3998721	47.7886906
20	1241.012	378.260	1255265.31955	290806.34891	122.4001688	47.78648539
21	671.060	204.539	1255585.70242	289675.48735	122.3987723	47.78340369
23	687.709	209.614	1255242.12085	287824.17745	122.4000162	47.77831027
24	1075.474	327.804	1255099.04446	286840.27195	122.4005165	47.77560549
25	624.905	190.471	1255480.51181	286100.91654	122.3989043	47.77360028
26	1020.336	310.998	1255443.43551	284944.47217	122.3989594	47.77042851
27	1337.614	407.705	1256242.24734	283643.26021	122.3956042	47.76690652
Proposed Outfall Alignments	LENGTH(FT)	LENGTH(M)	Offshore Easting(X)	Offshore Northing(Y)		
alignment 6	5818.935	1773.611	1251200.0000	299300.0000	122.4174135	47.80953741
alignment 7N Deep	7447.315	2269.942	1251200.0000	290600.0000	122.4166851	47.78569172
alignment 7N Shallow	3651.370	1112.938	1253700.0000	294700.0000	122.4068588	47.79706993
alignment 7S Deep	5048.762	1538.863	1251600.0000	287000.0000	122.4147574	47.77584707
alignment 7S Shallow	3300.000	1005.840	1253600.0000	290000.0000	122.4068746	47.78418213
Diffuser Sites (Up Slope Point)			Easting(X)	Northing(Y)	Longitude(X)	Latitude(Y)
7n			1254294.42578	294718.24991	122.4044423	47.79715324
7s			1254315.13430	290013.06584	122.4039674	47.78425799

Population Density Transect Lines				
Line Number	Onshore Easting(X)	Onshore Northing(Y)	Onshore Longitude(X)	Onshore Latitude(Y)
1	1263278.02478	305629.70743	122.3687841	47.82755754
2	1262565.89589	304929.65786	122.3716256	47.82559978
3	1261869.96169	304193.30714	122.3743981	47.82354334
4	1261312.28154	303370.82794	122.3766007	47.82125837
5	1260886.86848	302507.63798	122.3782615	47.81886905
6	1260281.09913	301648.04609	122.3806563	47.81647962
7	1259702.08574	300973.52610	122.3829573	47.81459889
8	1259018.29136	300246.50658	122.3856801	47.81256842
9	1258310.63502	299742.03844	122.3885181	47.81114656
10	1257732.33373	299353.93555	122.3908392	47.81005075
11	1257062.82036	298639.16010	122.3935043	47.80805444
12	1256053.98067	297659.15081	122.3975279	47.8053122
13	1255854.55387	296967.94971	122.3982821	47.80340657
14	1255617.48180	295933.46439	122.3991609	47.80055794
15	1255329.82443	294615.31970	122.4002219	47.79692899
16	1255459.75935	294023.17255	122.3996444	47.79531323
17	1255901.11047	293147.32064	122.3977767	47.79293722
18	1256430.02787	292387.09223	122.3955625	47.79088296
19	1256462.29751	291397.39567	122.3953495	47.7881721
20	1256465.28916	290489.83061	122.3952624	47.78568472
21	1256256.75719	289672.85077	122.3960431	47.78343385
23	1255914.78409	287967.24223	122.3972928	47.7787399
24	1256145.40785	287088.80339	122.3962824	47.77634503
25	1256101.34455	286172.13838	122.3963859	47.77383009
26	1256415.49907	285254.59880	122.3950328	47.77133268
27	1257253.14064	284519.22027	122.3915666	47.76936362
Proposed Outfall Alignments	Onshore Easting(X)	Onshore Northing(Y)		
alignment 6	1256700.0000	297400.0000	122.3948782	47.80463786
alignment 7N Deep	1257350.0000	294800.0000	122.3920195	47.79754764
alignment 7N Shallow	1257350.0000	294800.0000	122.3920195	47.79754764
alignment 7S Deep	1256600.0000	287700.0000	122.3944844	47.77804555
alignment 7S Shallow	1256900.0000	290000.0000	122.3934541	47.78436631
Diffuser Sites (Up Slope Point)				
7n				
7s				

TABLE 1 MOSS Geoduck Sampling Positions						
Geoduck Tissue Sample Sites	Aprox. Depth (ft)(mllw)		Easting(X)	Northing(Y)	Longitude(X)	Latitude(Y)
GDK5-1E	20		303612.0000	1260653.0000	126.5557347	50.31865352
GDK5-1W	20		303612.0000	1260653.0000	126.5557347	50.31865352
GDK5-2E	45		303997.0000	1260055.0000	126.5539027	50.31709887
GDK5-2W	45		303997.0000	1260055.0000	126.5539027	50.31709887
GDK5-3E	70		304280.0000	1259554.0000	126.5525367	50.31578834
GDK5-3W	70		304280.0000	1259554.0000	126.5525367	50.31578834
GDK6-1E	20		297921.0000	1256090.0000	126.5785501	50.30503344
GDK6-1W	20		297921.0000	1256090.0000	126.5785501	50.30503344
GDK6-2E	45		297864.0000	1256078.0000	126.5787893	50.30498903
GDK6-2W	45		297864.0000	1256078.0000	126.5787893	50.30498903
GDK6-3E	70		297884.0000	1256009.0000	126.578682	50.3048047
GDK6-3W	70		297884.0000	1256009.0000	126.578682	50.3048047
GDK7-1E	40		289812.0000	1256135.0000	126.6131371	50.30349517
GDK7-1W	40		289812.0000	1256135.0000	126.6131371	50.30349517
GDK7-2E	45		289814.0000	1256077.0000	126.61311	50.30333721
GDK7-2W	45		289814.0000	1256077.0000	126.61311	50.30333721
GDK7-3E	70		289808.0000	1255710.0000	126.6130178	50.30233386
GDK7-3W	70		289808.0000	1255710.0000	126.6130178	50.30233386
Study Area	605 Acres					

Geoduck Tissue Sample Sites				
GDK5-1E				
GDK5-1W				
GDK5-2E				
GDK5-2W				
GDK5-3E				
GDK5-3W				
GDK6-1E				
GDK6-1W				
GDK6-2E				
GDK6-2W				
GDK6-3E				
GDK6-3W				
GDK7-1E				
GDK7-1W				
GDK7-2E				
GDK7-2W				
GDK7-3E				
GDK7-3W				
Study Area				